RADIATION PROTECTION

ICRP PUBLICATION 15

Recommendations of the International Commission on Radiological Protection

Protection against Ionizing Radiation from External Sources

A Report of ICRP Committee 3
Adopted by the Commission in November 1969

PUBLISHED FOR
the International Commission on Radiological Protection
BY
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DEDICATION

BRIAN ERNEST JONES
1927–1969

THE SUDDEN death of Brian Jones on 28 November 1969 was a severe loss to all his colleagues in the field of radiological protection. His hard work and enthusiasm as secretary of the Task Group responsible for the preparation of this report are particularly appreciated. It is accordingly the wish of the Commission and of those who worked with him on this task that the report should be dedicated to his memory.

CONTENTS

Preface vii

Introduction 1

Quantities and units 1

ABSORBED DOSE, EXPOSURE AND DOSE EQUIVALENT 2
MODIFYING FACTORS 2
DETERMINATION OF DOSE EQUIVALENT 3
DERIVATION OF DOSE EQUIVALENT FROM PARTICLE FLUENCE 4

Recommendations on design and operation 4

GENERAL RECOMMENDATIONS 4
Recommendations relating to specific types of equipment 7
X-ray equipment and particle accelerators 7
Beam equipment with sealed radioactive sources 7
Sealed sources used without beam collimation 8

MEDICAL USES OF RADIATION 9
General recommendations 9
Diagnostic installations 10
X-ray diagnostic installations 10
Fluoroscopy 11
Radiography 12
Photofluorography 13
Dental radiography 13
Diagnostic uses of radioactive substances 14
Therapeutic installations 14
Beam therapy 14
Conventional x-ray therapy 14
Superficial x-ray therapy 15
"Megavolt" x-ray and particle beam therapy 15
Sealed source beam therapy 16
Non-collimated sealed source therapy 16
Therapy with unsealed sources 17
Protection of the patient 17
Introduction 17
Recommendations with regard to operational procedures 19
General 19
X-ray diagnosis 19
Fluoroscopy 19
Radiography 20
Dental radiography 21
Radiotherapy 21
Medical research 21

VETERINARY USES OF RADIATION 21
General requirements 21
X-ray diagnosis 21
Radiotherapy using x rays and sealed radioactive sources 23
The use of unsealed radioactive substances 23

INDUSTRIAL USES OF RADIATION 23
General requirements 23
Industrial radiography 24
Enclosed installations 24
Open installations 24
X rays 24
γ rays 25
Long-term storage 25
Temporary storage 25
Handling and use 25
Industrial fluoroscopy 26
Industrial gauges and similar equipment 26
X-ray analytical equipment 26
RESEARCH USES OF RADIATION 28
USE OF RADIATION IN EDUCATION 29
MISCELLANEOUS SOURCES AND USES OF RADIATION 29
RADIATION AS AN UNWANTED BYPRODUCT 30
Survey and monitoring 30
GENERAL REQUIREMENTS 30
MONITORING 31
Personal monitoring 31
Individual monitoring 31
Monitoring of the work place 31
Environmental monitoring 32
RECORD KEEPING 32
References 33
Appendix: SUMMARY OF DOSE LIMITS FOR INDIVIDUALS 34

PREFACE

In April 1967 the International Commission on Radiological Protection appointed a Task Group consisting of

P. Grande (*Chairman*)
K. Becker (*Vice-Chairman*)
B. E. Jones (*Secretary*)
J. P. Kelley
K. Koren
C. B. Meinhold
P. Pellerin
R. H. Thomas

to consolidate, modify and expand the material previously published in ICRP Publications 3 and 4 into a new report on protection against external radiation, covering medical, industrial and research uses of all types of ionizing radiation, essentially up to energies of 100 MeV and with the main emphasis on the medical uses. The recommendations in the present report have been made by Committee 3 on the basis of the suggestions and the material compiled by the Task Group. The recommendations relating to protection of the patient have also been based upon advice received from members of the ICRP Task Group on the Protection of the Patient in X-ray Diagnosis.

A supplement to this report is being published separately; it contains data that have been prepared by the Task Group for the purpose of providing reference material which will allow quantitative assessments to be made of primary and secondary radiation fields and of the effectiveness of protective walls and barriers.

Membership of Committee 3 (1965–9)

B. Lindell (*Chairman*)
E. E. Smith (*Vice-Chairman*)
L.-E. Larsson (*Secretary*)
F. P. Cowan
J. Dutreix
S. Takahashi†
E. D. Trout
H. O. Wyckoff

† Joined in 1967.

INTRODUCTION

(1) It is the Commission's wish to maintain fully its traditional contact with medical radiology and to fulfil its responsibilities to the medical profession; it is therefore appropriate that the Commission should give guidance and recommendations on the safe use of ionizing radiation and radioactive substances having regard to the external exposures that will occur from this use.

(2) The radiation sources that are used for non-medical purposes are often similar to those that are used in medical diagnosis or therapy, and the basic precautions to protect the staff are essentially the same irrespective of the use. It has therefore been felt that an extension of the recommendations to cover also veterinary and industrial uses and research applications of radiation would be justified. The corresponding sections are, however, less extensive than those dealing with the medical uses.

(3) By utilizing the practices outlined in this report, it should in general be possible to maintain radiation doses below the maximum permissible levels recommended by the Commission (ref. 9) and to provide adequate protection to the patient. The national regulatory authorities are, however, expected to establish the necessary standards and control procedures and to expand detailed technical requirements. For guidance, it has been considered desirable to publish a supplement to this report, containing graphs, tables and examples from which the necessary numerical values for radiation protection can be obtained.

(4) The current maximum permissible doses that are recommended for exposure to internal and external radiation are summarized in the Appendix to this report.

(5) It should be stressed that recommendations for the installation and operation of x-ray and other equipment producing ionizing radiation or for dealing with radioactive materials are not in themselves sufficient to guarantee adequate protection. Such protection depends also on the knowledge of the staff and on their co-operation in carrying out the instructions prepared by their supervisors in the interest of radiation protection.

(6) In the recommendations given in this report, the words *shall* and *should* have the following meaning:

> *shall*—necessary or essential for adequate protection against radiation;
> *should*—to apply, whenever practicable, in the interests of improving radiation protection.

The Commission is aware that compliance with some of the *new* recommendations may entail structural changes in existing installations and/or changes in operative procedures. It is desirable that such changes be made as soon as practicable, but not in such a way as to deprive patients of necessary medical attention (see also paragraph 38).

QUANTITIES AND UNITS

(7) This section gives a brief review of the basic concepts and units used in the evaluation of Absorbed Dose and Dose Equivalent. Reference is given to material in the supplement to this report and elsewhere which will be of help in the solution of the practical problems of radiation protection.

ABSORBED DOSE, EXPOSURE AND DOSE EQUIVALENT

(8) *Absorbed dose* (*D*) due to any directly or indirectly ionizing radiation is the energy imparted to matter by ionizing particles per unit mass of irradiated material. The special unit of absorbed dose is the *rad* and is equal to an energy absorption of 0.01 joule kg^{-1} or 100 ergs g^{-1} (ref. 16).

(9) *Exposure* (*X*) is the term reserved for the quantitative assessment of ionizing electromagnetic radiation fields. The exposure at a given place is a measure of the radiation based upon its potential ability to produce ionization in air. The special unit of exposure is the *roentgen* (*R*). One roentgen is the exposure of x- or γ-radiation such that the associated corpuscular emission per kilogram of air produces, in air, ions carrying 2.58×10^{-4} coulombs of electric charge of either sign (ref. 16).† For a wide range of energies one roentgen will result in an absorbed dose in soft tissue of approximately one rad under conditions of charged particle equilibrium.

(10) The *kerma* is a dosimetric measure of the radiation field for uncharged particles such as neutrons or x rays. It is equal to the kinetic energy of charged particles generated per unit mass of the material with which the uncharged particles interact. A unit of kerma is the rad.

(11) Equal absorbed doses of radiation may not always give rise to equal risks of a given biological effect, since the biological effectiveness may be affected by differences in type of radiation or irradiation conditions. To apply risk estimates obtained under a given set of conditions to situations in which other types of radiations are used or the conditions of irradiation differ, e.g. with regard to the spatial distribution of absorbed dose it is necessary to multiply the absorbed dose for each type of radiation by one or more weighting factors. In radiological protection the quantity obtained by thus weighting the absorbed dose in rads is called the *dose equivalent* (*DE*) and its unit is the *rem*. The dose equivalent for a given type of radiation and at a given location in the body is numerically equal to the product of the absorbed dose in rads for that radiation at that position and the modifying factors specified by the Commission. The dose equivalent for a given radiation may thus be expressed by the equation:

$$(DE) = D \times (MF)_1 \times (MF)_2 \times \ldots (MF)_i,$$

where (*DE*) is the dose equivalent in rems, *D* is the absorbed dose in rads, and $(MF)_1 \ldots (MF)_i$ are appropriate modifying factors.

When more than one type or energy of radiation is present at the point of interest, the dose equivalent at that point may be obtained by summing the dose equivalents for each of the types and energies of radiation.

[MODIFYING FACTORS

(12) The modifying factor most frequently used is the *quality factor* (*QF*), which accounts for the difference in the linear energy transfer of different directly ionizing radiations at the location of interest.‡ The *linear energy transfer* (L_Δ), defined by the ICRU (ref. 16), includes a limit Δ for energy transfers from the charged particles. For protection purposes all energy transfers are included, and L_∞ becomes numerically equal to the collision stopping power. Table 1 gives the relationship between L_∞ and *QF*. Intermediate *QF*s may be obtained by an interpolation from the curve given in Appendix 2 of the supplement. When the incident radiation is x or γ rays, the quality factor of the electrons generated in any position within the body is assumed to be 1, and no other modifying factors apply.

† This is numerically equal to the former definition of 1 e.s.u. of electricity per 0.001293 g of air.

‡ Previously this modifying factor was termed the "RBE", but the use of this term for both radiobiology and protection purposes presents certain problems which are discussed in detail in the Report of the RBE Committee to the ICRP and the ICRU (ref. 14).

TABLE 1. L_∞-QF RELATIONSHIP

L_∞ in water (keV/μm)	QF
3.5 (and less)	1
7	2
23	5
53	10
175 (and above)	20

(13) In some situations the charged particles producing the absorbed dose at the point of interest may have a continuous energy or L distribution (strictly this should be L_∞, but for convenience this has been simplified to L). In that case the dose equivalent is obtained from

$$DE = \int_0^{L_{max}} D(L)QF(L)\,dL,$$

where $D(L)$ is the absorbed dose at the point of interest per unit interval of L at L, $QF(L)$ is the quality factor for this L, and L_{max} is the maximum value of L at the point of interest. Then the effective quality factor, $\overline{QF}$, is given by

$$\overline{QF} = \frac{\int_0^{L_{max}} D(L)QF(L)\,dL}{\int_0^{L_{max}} D(L)\,dL}.$$

(14) *Additional modifying factors:* Further modifying factors might become necessary in certain cases. In the future it may be possible to recommend modifying factors to allow for, among other things, non-uniform spatial distribution of absorbed dose, differences in absorbed dose rate or for fractionation of absorbed dose.

DETERMINATION OF DOSE EQUIVALENT

(15) For radiation protection purposes one must determine the dose equivalent in the critical organs and compare these numerical values with the maximum permissible dose for that organ. However, neither the absorbed dose nor the dose equivalent can be measured directly in any of the critical organs. Thus to obtain the dose equivalent in any position within the body one must make measurements of the radiation fields outside of the body. These measurements, together with determinations of the relative depth dose in the body, permit determination of the dose equivalent at various locations.

(16) For incident monoenergetic radiation of a given type the dose equivalent tends first to increase with depth, then to reach a maximum and finally to decrease. The increase may be due to a buildup of charged particles from an incident uncharged particle beam, to scattering of the incident radiation near the entrance portion of the body or to production of secondary radiations of other types. The decrease of the dose equivalent results from attenuation of the primary beam. The position of the maximum dose equivalent in the body depends upon the energy and type of radiation. When a radiation passes through a shield before reaching the person whose irradiation is to be determined, the increase in the dose equivalent with depth of the body is reduced because much of this increase might take place in the shield itself. Moreover, if the person's orientation is not fixed with respect to the radiation, the peaks tend to be "smeared out". Similar "smearing out" will occur if the radiation is more or less isotropically incident upon the body.

(17) Depending upon the information available with respect to type and energy of radiation, various approximations may be used to assess the value of the dose equivalent in the critical organs (but see paragraph 18). When the incident radiation is x or γ rays, the exposure in roentgens measured outside the body may be assumed to be numerically equal to the absorbed dose in rads at any position in the body and, since the QF is 1, also equal to the dose equivalent at any point in the body. When the incident radiation is neutrons only and the tissue kerma free in air (in rads) is known, this kerma may be assumed to be numerically equal to the absorbed dose in rads at any point in the body. If the energy of these incident neutrons is not known, a QF of 10 should be assumed. Alternatively a measurement with a "rem-meter" may give an adequate determination of the dose equivalent. For singly charged heavy particles of unknown energy, a QF of 15 is recommended, while for multiply-charged particles (or particles of unknown

charge) of unknown energy, a *QF* of 20 should be used. If the energy of such charged particles is not known, it may be assumed that the absorbed dose in tissue obtained free in air will be the absorbed dose at any place in the body.

(18) The above approximate determinations of the absorbed dose and the dose equivalent in the critical organs are adequate when the numerical values so obtained are well below the maximum permissible doses or dose limits (as the case may be) for the organs that are critical in the case of whole-body exposure (i.e. the red bone marrow and the gonads). More accurate assessments are required when the approximate determinations give values close to or exceeding the MPDs or dose limits.

DERIVATION OF DOSE EQUIVALENT FROM PARTICLE FLUENCE

(19) An alternative approach to the estimation of the dose equivalent by the use of quality factors and an assessment of absorbed dose is to convert the particle fluence incident upon the body directly by the use of conversion factors. Appendices 6 and 7 give values of factors for conversion of particle fluence to dose equivalent for neutrons and protons respectively. In calculating the values for the conversion factors those irradiation conditions have been selected which lead to the highest values of the dose equivalent.

RECOMMENDATIONS ON DESIGN AND OPERATION

GENERAL RECOMMENDATIONS

(20) The following recommendations on general principles for operational radiation protection are quoted from ICRP Publication 9 (ref. 9), and are relevant to this section of this report.

> "(108) In any establishment or operation the authority in charge should identify a technically competent person or persons to provide advice on all relevant aspects of radiation protection, and to provide such technical services as are needed in the application of appropriate recommendations for radiation protection. The authority itself would, however, be responsible for the protection of persons working in the establishment or on an operation and for limiting the exposure of members of the public, so as to comply with the relevant national or local requirements.
>
> "(109) The design of all projected installations and the plans for all operations should be evaluated in advance for the adequacy of radiation protection, both of workers and of members of the public. The evaluation of radiation protection should also include a review of foreseeable types of accidents. This review should consider the nature and magnitude of foreseeable accidents, their probability of occurrence, their consequences, and the appropriate preventive measures and counter-measures.
>
> "(113) The authority in charge should establish such controlled areas as may be necessary. A controlled area is any area to which access is controlled for the purpose of protecting persons from exposure to radiation or radioactive materials. Access can be controlled in a variety of ways, the minimum being by the use of warning signs. The extent of a controlled area is a matter of professional judgement, but in all cases the extent should be such that it is extremely unlikely that workers outside the controlled area will receive doses in excess of 3/10 of the appropriate Maximum Permissible Doses. Other considerations may require an enlargement of the controlled area.
>
> "(114) Workers should be suitably in-

formed of the radiation hazard entailed by their work and of the precautions to be taken. This will require training in safe procedures and in effective methods of avoiding unnecessary exposure.

"(115) Necessary protective equipment should be provided and its appropriate use should be enforced.

"(116) Working conditions and equipment should be reviewed from time to time to ensure that they remain as intended. They should also be reviewed when an operation is modified.

"(124) The authority in charge of any establishment or operation which might cause environmental contamination should limit the exposure of members of the public so as to comply with relevant national or local requirements, and with the Commission's recommendations, by controlling the release of radioactive material into the environment. Any radiation sources which might cause public exposure by external radiation should be subject either to adequate shielding or restrictions of access."

(21) The final plans for new installations or for modifications of existing installations involving structural shielding should be reviewed by a qualified expert and should be approved by the competent authority before building is commenced. Copies of the plans of the installation, including the shielding specifications, should be retained and be readily available at the site.

(22) Before any equipment or installation is put into use, surveys shall be carried out in order to establish that the approved plans have been followed and that the shielding and operating conditions are such as to provide protection for all persons in accordance with national and local requirements and/or the recommendations of the Commission. For details on surveys and monitoring, see paragraphs 290–307. Subsequent surveys shall be made after every change in the equipment, installation or conditions of use that might affect the protection and at such intervals as may be necessary to check that satisfactory conditions still obtain.

(23) Protection can be achieved by distance, by shielding and by reduction of the exposure time. Proper siting of the installation and limitations of the possible directions of the useful beam are examples of means by which the cost of the shielding can be reduced.

(24) The shielding of the radiation source and the dimensions and siting of the installation in which it is situated shall be such that work can be carried out in compliance with the recommended maximum permissible doses and dose limits for workers and members of the general public. In the case of work that is undertaken outside fixed installations (e.g. site radiography), temporary barriers and warning signs to restrict access to the controlled area shall be used when necessary. In the supplement to this report absorption data and other information are provided for the computation of shielding requirements.

(25) In the planning of a radiation installation, account should be taken of the maximum practicable workload of the equipment.

(26) The shielding requirements depend on the nature of the occupancy of surrounding areas, that is whether (either as controlled areas or not) they are accessible to adults during their work or to members of the public (including patients). For some areas it may be possible to employ "occupancy factors" and "use factors" in order to reduce the shielding requirements. Since these factors may differ considerably between installations, no recommendations regarding their magnitude are given in this report. Where such factors are employed, relaxations of the shielding requirements always need careful consideration and shall be in conformity with the requirements of the relevant national or local authority. Attention should also be paid to shielding of certain areas such as those used for storage of x-ray film or other sensitive radiation detectors.

(27) In calculating the shielding, consideration should be given to the possible irradiation of persons of all categories from other sources of radiation, including irradiation from internal sources (see ICRP Publication 9 (ref. 9), paragraphs 53 and 71, footnote to paragraph 68; ICRP Publication 12 (ref. 12), paragraphs 12–14).

(28) In calculating the shielding required against the primary radiation beam, removable objects (e.g. patient, phantom, casting) by which the beam may be partly absorbed should not normally be taken into account. Exceptions to this recommendation should

only be permitted with the agreement of the competent authority.

(29) In calculating the shielding required against stray radiation,† the anticipated conditions of use which give rise to the maximum leakage radiation from the equipment and the maximum secondary radiation should be assumed.

(30) Windows and doors of radiation rooms shall be subject to the same protection requirements as the adjacent parts of the walls in which they are located. It should be noted that the shielding requirements of a door are reduced if there is a shielded entrance maze between it and the radiation area.

(31) Shielding materials such as lead shall be mounted in such a manner that they will not creep under their own weight. They shall also be protected against mechanical damage. When materials such as concrete, particularly when they are cast on site, are intended to provide radiation shielding, care must be exercised to ensure that they are sufficiently homogeneous and are of the composition and density specified by the competent authority.

(32) In building a radiation installation, care should be taken to ensure that the shielding is not impaired at joints, nails, bolts, etc., where pipes, conduits and louvres, etc., are present and at the edges of doors and windows. At a joint between two different shielding materials the overlap shall be not less than the required thickness of the material of the lower protective capability.

(33) Where appropriate, the nature of and the shielding provided by walls and other barriers which form part of the shielding of an installation should be marked upon them.

(34) Wherever practicable, locks or interlocks should be provided which preclude access to radiation areas while the rate of irradiation exceeds acceptable levels (see paragraph 41).

(35) Suitable devices such as diaphragms, cones and adjustable collimators shall be used to limit the useful beam.

(36) Where equipment has been found to comply with existing recommendations or requirements it should, when practicable, be labelled to this effect. Auxiliary equipment such as filters and treatment cones should be marked with the relevant properties in a manner that will prevent unintentional substitution and misuse.

(37) Wherever practicable, equipment that may emit significant amounts of radiation should be provided with a label by which it can be identified as a potential source of radiation.

(38) Equipment that does not and cannot be made to meet modern requirements shall not be retained against the advice of competent experts. No equipment shall be used for other purposes than those for which it has been designed unless it has been surveyed and tested, and certified as satisfactory for the new purpose. Obsolete equipment shall not be handed over to other users unless it will be subject to such surveillance and testing for safe functioning. Particular attention shall be given to the possible misuse of equipment in common use (for example, dental units). The use of modern equipment should be encouraged, but it should also be recognized that there are circumstances where unconditional disapproval of existing equipment merely because it is old may result in unjustified deprivation of valuable medical attention.

(39) In carrying out surveys it is essential to use instruments that are of adequate sensitivity, properly calibrated and suitable for the types of radiation that may occur (see paragraph 294).

(40) In assessing compliance with the requirements for tube and source housings it is adequate for measurements to be averaged over an area up to but not larger than 100 cm^2 at a source distance of one metre or 10 cm^2 at a distance of 5 cm from the tube or source housing, as appropriate.

(41) All controlled areas as defined by the Commission (see paragraph 20:113) shall be identified by appropriate and adequate signals and signs which can be readily recognized by all persons to whom they are intended to give warning. In order to avoid uncertainties in the determination of the extent of controlled areas the boundaries should when possible be walls, doors, etc. Inside controlled areas it may sometimes be useful to indicate where certain rates of irradiation occur.

(42) The information and training of

† Radiation other than the useful beam. It includes leakage radiation and secondary radiation.

workers referred to in paragraph 20:114 should particularly emphasize the importance of distance, time and shielding. Training should be aimed at optimizing these factors, with particular attention paid to the importance of avoiding exposure of any parts of the body to primary beams.

(43) Attention is drawn to the possible existence of non-radiological hazards such as electrical, mechanical and toxic hazards (e.g. the production of ozone and oxides of nitrogen). Information on these hazards should be obtained from national regulations or codes of practice.

Recommendations relating to specific types of equipment

(44) In this report the recommendations are mainly presented on the basis of the type of use of radiation rather than on the basis of the nature of the radiation source. However, a few recommendations specifically related to type of source are given in paragraphs 45–66.

X-ray equipment and particle accelerators

(45) The exposure outside any auxiliary equipment, e.g. high tension generators, shall not exceed 20 mR in one hour at 5 cm from the surface (see paragraph 40), nor 2 mR in one hour at any readily accessible place within the controlled area. If the transformer or valve enclosure is located outside the controlled area, it may be necessary to reduce these exposures.

(46) A reliable indication shall be provided at the control panel and, when practicable, also readily visible near the radiation beam aperture in order to show whether or not radiation is being generated. When appropriate, signs should also be displayed outside the irradiation room.

(47) Warning indicators should be so designed that they will not give rise to a false feeling of safety; e.g. lights indicating when the tube is *not* energized may be provided in addition to lights indicating that radiation is being generated. Alternatively, lights of the latter type may be so designed that the equipment cannot be operated if there is a failure of the indicator.

(48) Where the primary beam strikes material, secondary radiation will be generated. Attention should be given to the choice of material and the arrangement of absorbers to minimize the secondary radiation, which will include x rays when electrons or beta particles are absorbed.

(49) High energy accelerators may produce noxious gases, and materials (including air and dust) irradiated by the accelerated particles or by the photon beam may become activated. Expert advice on these problems should be obtained at the planning stage and any necessary safety measures, e.g. choice of material and the installation of forced ventilation, should be incorporated in the design. Material that may become activated (shielding material, machine components, conveyor systems, beam defining system and sample holders) should be monitored and any appropriate precautions instituted.

Beam equipment with sealed radioactive sources

(50) In the design of source housings consideration should be given to means whereby the integrity of the source housing is preserved in the event of fire. Information on the location of major radioactive sources should be readily available to the appropriate fire authorities.

(51) A reliable indication shall be provided at the control panel and, when practicable, also at the source housing, in order to show when the source is in the ON position. It is often advisable also to have an indication capable of showing when the source is in the OFF position (see paragraph 47). When appropriate, signs should also be displayed outside the irradiation room.

(52) The surface of the housing of the source capsule, particularly the beam aperture, together with any other locations likely to be contaminated in the event of a leakage, shall be tested for leakage of radioactive material at least every year. Guidance on methods of testing sealed sources is given in ICRP Publication 5 (ref. 5). Should the probable presence of free activity of more than 0.05 μCi be indicated, the source shall be considered as leaking, the equipment with-

drawn from use and arrangements made immediately for source repair and decontamination of the equipment.

Sealed sources used without beam collimation

(53) A sealed source is considered to be any radioactive substance sealed in an inactive container or capsule, or bonded wholly within inactive material, so as to prevent dispersion of the radioactive substance during routine use. It should be noted that many sealed sources are fragile and may easily be damaged with consequent release of the radioactive material. A sealed source may normally be regarded as exempted from the following recommendations if it consists of not more than 1 μCi of Group 1 radionuclides (ref. 5) or 100 μCi of other radionuclides and would not give rise to a dose equivalent rate of more than 10 mrem/h at or near its surface.

(54) Sealed sources containing activities exceeding those specified in paragraph 53 will need to be recognizable as such, for two reasons. One is that the layman should be warned of the fact that the source is radioactive (this is particularly important with sources used for industrial radiography); the other is that the expert will need an easy way of identifying the nature and the activity of the radioactive material. Hence, wherever practicable, all such sources should be readily recognizable as being radioactive and the source container, capsule or bonding shall be labelled in such a way that the source can be identified (see paragraph 144). If practicable, the nature and the activity of the radioactive material should be marked directly on the label.

(55) A register shall be kept of all sealed sources. The register should include:

- the serial number or other identification of each sealed source;
- the nature of the radioactive substance, the date of receipt and its activity on that date;
- the date and manner of ultimate disposal from the establishment.

(56) Records shall be kept of the movement of all sealed sources within and outside an establishment in order to minimize the possibility of their loss. Actual or suspected loss of, or damage to, a sealed source shall be reported immediately to the person responsible for radiation protection.

(57) The storage, use, issue and receipt of sealed sources shall be the responsibility of authorized persons only, and an audit of all sealed sources shall be carried out at appropriate intervals and at least every year.

(58) Extreme care shall be taken to avoid mislaying sealed sources. This is particularly important in the case of open installations (see paragraph 220) where a mislaid source may get into the possession of an unsuspecting person.

(59) Local rules shall be prepared detailing the manner of use of sealed sources and the procedures to be adopted in the event of loss of, damage to, or accidents involving a sealed source. In preparing such rules, consideration should be given, as appropriate, to factors such as possible causes of loss, spread of contamination, effects of fire, and identification and treatment of casualties.

(60) When not in use, sealed sources shall be stored under conditions which provide adequate protection for those entering and adjacent to the store, security against unauthorized removal and minimum risk due to fire and flood. Where sources are liable to release a radioactive gas or vapour the store shall, if necessary, be mechanically ventilated to the outside air. Such ventilation may need to be continuous, or for an appropriate period before and whilst the store is open, depending upon the activity and radiotoxicity of the radionuclide concerned.

(61) Sealed sources shall be tested for leakage at appropriate intervals and at least every year. Guidance on methods of testing is given in ICRP Publication 5 (ref. 5). If the probable presence of free activity of more than 0.05 μCi is indicated, the source shall be considered as leaking.

(62) Whenever there are reasonable grounds for believing that a sealed source is, or is liable to be, leaking, it shall be hermetically sealed in a suitable container pending repair by the manufacturer or by a competent establishment. In such circumstances the area in which the source has been used and any person having used it shall be checked for contamination.

(63) In order to ensure the minimum irra-

diation of personnel engaged in the preparation or application of sources, appropriate handling tools or implant instruments shall be used at all times. These tools shall be constructed so as to provide the maximum handling distance compatible with effective manipulation. All operators shall have adequate training, e.g. with dummy sources, in these manipulative procedures. Whenever practicable, remote means of manipulation, which ensure adequate protection of the staff, shall be used.

(64) The transport of sources shall be carried out in such a manner that all individuals are adequately protected. Where the total activity is low, sources may be transported by hand in a long-handled container. While being used for the transport of sources such containers shall be distinguished by suitable markings and shall either be under surveillance or be inaccessible to unauthorized persons. The intended use (nuclides, maximum activities) shall be marked on the transport containers.

(65) An encapsulated source intended for the utilization of β radiation requires a thin window. This window and its mounting shall be so constructed as to minimize the risk of leakage of radioactive material, and when not in use shall be covered by a shield of sufficient thickness to absorb all the β radiation. When the window is being cleaned, or the source tested for leakage, care shall be taken to avoid damaging the window.

(66) It should be recognized that all β-ray sources will emit bremsstrahlung and may emit other types of penetrating radiation such as γ rays, annihilation radiation and characteristic x rays. Possible exposures from such radiations shall be evaluated and the necessary precautions taken. Although the production of bremsstrahlung may be minimized by absorbing the beta rays with a material of low atomic number, the bremsstrahlung may still be excessive. In such cases it may be necessary to provide an outer shield of high atomic number to attenuate the bremsstrahlung. It is therefore usually advantageous to make the whole shield of a material of high atomic number since its attenuation properties will outweigh the increased bremsstrahlung production.

MEDICAL USES OF RADIATION

General recommendations

(67) The recommendations in this section on the medical uses of radiation are primarily intended for the protection of persons operating or using radiation sources. However, many of the recommendations on equipment also provide for the protection of the patient; these paragraphs have been marked with an asterisk. The subject of the protection of the patient is dealt with more comprehensively in a special subsection (paragraphs 150–194) which contains further recommendations on operational procedures.

(68)* When more than one tube can be operated from a single control panel, there shall be indication at or near the tube housing and on the control panel showing which tube is connected.

(69)* Field defining cones and applicators shall be clearly marked with the appropriate field size and other relevant data.

(70)* A device shall be provided which will automatically terminate the exposure after a pre-set time or exposure has elapsed (see also paragraphs 93, 104 and 128). The proper functioning of timers is of particular importance and special attention should be given to those components which may wear out or become detached and, in consequence, cause malfunctioning of the timer.

(71)* The patient shall be observable from the control position. Means should be provided for communication with the patient.

(72)* The simultaneous examination or treatment of more than one patient in the same room may introduce unnecessary and not easily controllable hazards for both personnel and patients and should not take place. Wherever such arrangements are necessary, adequate protection shall be ensured for all persons involved.

Diagnostic installations

(73) All the appropriate provisions of the general recommendations (paragraphs 20–72) shall apply.

(74) The following paragraphs are mainly related to x-ray diagnostic procedures. Diagnostic uses of radioactive substances are referred to only in paragraph 119, since the radiation exposure from such uses is mainly internal exposure. With regard to the latter the reader is referred to the relevant ICRP publications (refs. 2, 5 and 10).

X-ray diagnostic installations

(75)* Every x-ray tube used for diagnostic purposes shall be enclosed in a housing such that the exposure from the leakage radiation measured at a distance of one metre from the focus does not exceed 100 mR in one hour at every rating specified by the manufacturer for that tube in that housing. (For the areas over which these measurements shall be made, see paragraph 40.)

(76)* Means (control settings or meters) at the control panel shall be provided to indicate tube potential and current when these can be varied.

(77)* Diaphragms, cones or collimators shall be used to limit the useful beam to the area of clinical interest and shall be so constructed that, in combination with the tube housing, they comply with the exposure requirements for leakage radiation as given in paragraph 75. A light-beam localizer for indicating the cross-section of the useful beam should be used. The use of a "multi-plane" type collimator will usually result in a reduced integral dose to the patient, and less scattered radiation.

(78)* The minimum permanent total filtration† in the useful beam shall be determined by the maximum voltage specified for the tube in its housing. The permanent total filtration for normal diagnostic work—including dental radiography—shall be equivalent to not less than:

1.5 mm Al at voltages up to and including 70 kV;
2.0 mm Al at voltages above 70 kV up to and including 100 kV;
2.5 mm Al at voltages above 100 kV.

Exception: In some special procedures at operating potentials below 50 kV (e.g. mammography), the minimum total permanent filtration shall be equivalent to at least 0.5 mm Al. (See paragraph 180 for filtration with direct fluoroscopy of the chest.)

(79)* The total filtration permanently in the useful beam as specified in paragraph 78 shall be indicated on the tube housing.

(80)* Some special radiographic procedures (e.g. mammography) require very soft radiation. Such procedures should be carried out on special equipment and not on standard x-ray equipment intended for higher potentials. Under no circumstances shall the total permanent filtration be equivalent to less than 0.5 mm Al. Where special equipment is not employed, means shall be provided which ensure that the tube is not used at higher potentials with inadequate filtration (see paragraph 78).

(81)* Various types of timers are required for fluoroscopic and radiographic work (see also paragraphs 93 and 104). The proper functioning of timers is of particular importance and special attention should be given to those components which may wear out or become detached and, in consequence, cause malfunctioning of the timer.

(82) No person shall remain in an x-ray room when radiological procedures are being carried out, unless his presence is essential.

(83) Persons who work within the x-ray department should not hold patients during diagnostic examinations. Motion-restricting devices shall be used as much as possible and cassettes shall never be hand-held during exposure. When children or other individuals must be held during an examination this should either be done by staff members of other departments or by parents or other persons accompanying them. If it is necessary to ask such staff members to hold patients,

† In actual practice, additional filtration is often appropriate; suggestions on suitable combinations of operating potentials and filtrations are given in the special report on the Protection of the Patient in X-ray Diagnosis (ref. 15).

a rotation system should be employed, subject to the applicable maximum permissible doses. No pregnant women or persons under the age of 18 years shall be permitted to hold patients. Those holding the patients shall wear protective aprons and gloves (see paragraphs 98 and 99) and should ensure as far as practicable that no part of their body, even if covered by protective clothing, is in the path of the beam.

(84)* Attention is drawn to the special problems associated with the use of x-ray diagnostic equipment in surgery. In this connection, particular attention is drawn to paragraph 20:108. The x-ray equipment and protective devices used should be such that they are not unnecessarily obstructive to the work of the surgeon or members of his staff; however, adequate protection shall be provided. Image intensifiers should be used for all surgical procedures requiring fluoroscopy.

(85)* Mobile equipment (i.e. equipment not used routinely at one location) should only be employed when it is impractical to move the patient to a fixed installation.

Fluoroscopy

(86)* An adjustable collimator or diaphragm shall be provided to define the useful beam.

(87) The x-ray tube, collimating device and fluoroscopic screen or image intensifier shall be linked together in such a way that, under normal operating conditions, the beam will not fall outside the screen irrespective of the source–screen distance. The so-called "hand fluoroscope" or "head fluoroscope" shall not be used.

(88) The fluorescent screen shall be covered with a protective glass sheet having a lead equivalent of not less than:

1.5 mm for apparatus having a maximum operating potential up to and including 70 kV;

2.0 mm for apparatus having a maximum operating potential above 70 kV up to and including 100 kV;

an additional 0·01 mm per kV above 100 kV.

Image intensifiers and adjacent mounting parts subject to useful beam exposure shall provide the same protection as that required for a conventional fluoroscopic screen assembly.

(89) If the equipment permits spotfilms to be taken in connection with the fluoroscopic examination, the beam should be intercepted by a barrier having a lead equivalent as specified in paragraph 88, with the maximum operating potential being equal to the highest potential at which such radiographic exposures can be made.

(90)* Under the conditions that obtain in direct fluoroscopy, screen definition is not a limiting factor in the perception of the image and therefore high sensitivity screens should be used (ref. 15). Old screens which are found to be much less sensitive than new ones should be replaced. The protective glass should be replaced if its optical density has increased significantly due to discoloration.

(91)* Recommended values for minimum distances between focus and patient are given in paragraph 92. The design of the equipment shall be such as to ensure that these distances cannot be less than those specified. In the case of mobile equipment, cones, diaphragms or spacer frames shall be provided to achieve this result.

(92)* In radiography and fluoroscopy with *mobile* equipment, the focus–skin distance shall not be less than 30 cm. In radiography and fluoroscopy (other than of the chest) with *stationary* equipment, the focus–skin distance shall not be less than 30 cm and should not be less than 45 cm. In fluoroscopy of the chest the focus–skin distance should not be less than 60 cm (see also paragraph 180) and, for equipment specifically and not only occasionally used for chest examinations, shall not be less than 45 cm. Photofluorography and radiography of the chest shall be performed with a focus–skin distance of at least 60 cm.†

(93)* The device referred to in paragraph 70 shall be supplemented with means for providing the fluoroscopist with an audible signal. The maximum setting of the device terminating the exposure shall not exceed 10 minutes; the setting of the audible signal shall be adjustable within the overall time.

(94)* The fluoroscopic exposure switch

† The recommended values are minimum values, and larger distances are often appropriate; e.g. in radiographic examinations of the chest. See also the special report on the Protection of the Patient in X-ray Diagnosis (ref. 15).

shall be of the "dead-man" type, i.e. a switch so constructed that the circuit-closing contact is maintained only by continuous pressure on the switch. It shall be located at the position occupied by the fluoroscopist and should be protected against accidental operation.

(95)* Means (control settings or meters) shall be provided to indicate the x-ray tube potential and current. These means should be located so that the values of voltage and current can be observed by the operator during cineradiography and by the fluoroscopist during fluoroscopy. Observation of these values is particularly important when using image intensifiers with "automatic brightness control" (automatic variation of either voltage or current, not under the direct control of the fluoroscopist, in order to maintain constant brightness).

(96) All tables and stands for fluoroscopy shall be provided with adequate means for protecting the fluoroscopist and his assistants against scattered radiation from the patient and from scattering materials between the source and the patient. A shield equivalent to not less than 0.5 mm lead shall be provided to cover openings such as the "Bucky slot". The fluoroscopist shall be protected by an "apron" or "drape" which may consist of overlapping parts to facilitate palpation. The apron shall have a lead equivalent of not less than 0.5 mm and dimensions of not less than 45 cm × 45 cm. It shall be attached to the lower edge of the screenholder when the latter is vertical and to the edge nearest to the operator when the screen is horizontal. A separate hinged or sliding panel shield should be located at the side of the table and should be of sufficient dimensions to protect the legs and feet of the fluoroscopist. When image intensifiers are used, the same protection shall be provided as is required for conventional fluoroscopy, particular attention being paid to stray radiation when the x-ray tube is located above the table.

(97)* Fluoroscopy shall not be carried out with mobile equipment unless an image intensifier is employed. The equipment shall be so constructed that the radiation beam is fully intercepted by the image intensifier.

(98) Whenever possible, members of the staff shall remain behind protective screens or shields during all types of fluoroscopic examinations. If this cannot be done, protective aprons having a lead equivalent of at least 0.25 mm shall be worn.

(99) Protective gloves having a lead equivalent of not less than 0.25 mm shall be worn when any fluoroscopic examination may involve placing the hands in or near the radiation beam. The gloves shall cover the whole hand including back, palm, fingers and wrist. Even when wearing protective gloves, the hands shall not be placed in the beam unless it has been attenuated by the patient.

(100)* The exposure rate for direct fluoroscopy as measured at the patient entrance surface should be as low as practicable and should not exceed 5 R/min.

(101)* Before a direct fluoroscopic examination is begun, the eyes shall be sufficiently dark-adapted. In order to enable work with the lowest possible exposure rate, the adaptation period should be at least 10 min. To avoid disadaptation when an examination has to be interrupted, either a coloured light or means to dim the room lighting shall be provided. The room illumination during such interruptions should not exceed 10 lux and preferably should be less than one lux. Alternatively red goggles should be worn during the interruption. When image intensifiers are used dark adaptation is normally not necessary. Excessive room lighting should, however, be avoided.

Radiography

(102)* The beam-defining system should be adjustable and provide rectangular fields. The proper limitation of the field to the area of clinical interest should be demonstrable on the film. Means shall be provided to verify that the film is aligned with the beam, and all edges of the beam should show on the film.

(103)* Recommended values for minimum distances between source and patient are given in paragraph 92 and, for dental radiography, in paragraph 113. The equipment shall be so operated that the actual distances are not less than these values. In the case of mobile equipment, cones, diaphragms or spacer frames shall be provided to achieve this result. Stationary equipment should, when practicable, be equipped with auxiliary devices in order to facilitate the distance control.

(104)* A device shall be provided to terminate the exposure after a pre-set time or exposure. If a recycling timer is used, it shall not be possible to make repeat exposures without release of the exposure switch to reset the timer except in the case of special techniques where repeated exposures are required.

(105)* Means (control settings or meters) shall be provided on the control panel to indicate the x-ray tube potential and current and the exposure time (or to indicate whether timing is automatic). A meter to indicate the product of milliamperes and time (mAs-meter) may be used in place of current and/or exposure time indicators.

(106) The operator shall be adequately protected during patient exposure. This may be achieved either by providing a shield for the operator within the x-ray room or by locating the control panel and operator outside the x-ray room.

(107) The x-ray exposure shall be controlled from the control panel only, except in the case of special techniques when it is necessary to control the exposure from the table or stand. In such special techniques, it may be necessary for the personnel to wear protective aprons and gloves (see paragraphs 98 and 99).

(108) The minimum distance of the operator from the tube and patient during mobile radiographic procedures shall be 2 m. High workloads may require that the operator stand behind an adequately shielded screen. The operator shall ensure that the only person exposed to the radiation beam, until it has been adequately attenuated, will be the patient.

Photofluorography

(109) In photofluorographic work paragraphs 87, 90–92, 102 and 104–107 shall apply wherever applicable.

(110)* High-efficiency optical systems, which enable the dose to the patient to be reduced, shall be used.

(111) *Mass* photofluorographic survey equipment shall be so arranged and shielded that all personnel associated with the procedure are adequately protected during routine use without the necessity for protective clothing.

Dental radiography

(112)* In dental examinations, the total filtration in the useful beam shall not be less than the values specified in paragraph 78. *Fluoroscopy* with dental equipment involves unnecessarily high exposure of the patient and shall not be used.

(113)* For conventional dental radiography (intra-oral radiography) a field-defining spacer cone shall be employed, which provides a minimum focus–skin distance of not less than 20 cm for equipment operating above 60 kV, and not less than 10 cm for equipment operating at 60 kV or below. Open-ended cylinders or divergent cones conforming with paragraph 77 should be used rather than the so-called "pointer" cones. The field diameter at the cone end should not exceed 6 cm and shall not exceed 7.5 cm.

(114)* X-ray equipment used for special dental radiography, e.g. the so-called panoramic equipment, "flash" (capacitor discharge) apparatus and equipment for cephalometric (profile) procedures, shall comply with the applicable recommendations in the section on medical x-ray radiography.

(115)* For conventional dental radiography the maximum range of the exposure timer should not exceed five seconds. The timer shall be capable of consistently reproducing the short exposure times needed for high-speed film. The exposure switch shall have a circuit-closing contact which can be maintained only by continuous pressure. It shall not be possible to make repeat exposures without release of the exposure switch. The timer (x-ray exposure) switch shall be so arranged that accidental exposure is unlikely.

(116) Dental installations shall be so arranged that the operator can remain outside the radiation beam at least 2 m from the tube and from the patient. Work-loads of more than 30 mA-min per week may require the use of an adequately shielded screen.

(117) Whenever possible the film shall be fixed in position or be held by the patient. The film shall never be held by the dentist or by a member of his staff.

(118) The tube housing shall not be held by hand during exposure.

Diagnostic uses of radioactive substances

(119) Most uses of radioactive substances for diagnostic purposes involve small activities and do not cause any significant external exposures. However, this may not be the case in certain procedures such as dispensing from stock solutions, injection of radioactive gases and the use of radioactive material in scanning techniques, particularly when short-lived nuclides are used. Whenever there is reason to believe that significant external exposure may occur, suitable protective measures shall be instituted. Recommendations on the handling of radioactive substances in hospitals are given in ICRP Publication 5 (ref. 5).

Therapeutic installations

(120) All the appropriate provisions of the general recommendations (paragraphs 20–72) shall apply.

Beam therapy

(121) No person other than the patient shall be in the irradiation room during any form of treatment, except that employing superficial therapy up to 50 kV (see paragraph 130).

(122)* All beam therapy equipment shall be calibrated by a qualified expert before it is first put into use for treatment, and at regular intervals thereafter. The initial calibration shall include measurements of the output, an assessment of the radiation quality and the beam homogeneity and a test of the constancy and reproducibility of all factors determining the radiation exposure. The minimum requirements in respect of the extent and frequency of repeat calibrations should be determined by the competent authority.

(123)* Although the need for door interlocks has been dealt with in paragraph 34, it should be noted that the interruption of a patient's treatment is undesirable. Appropriate additional measures shall therefore be taken to prevent inadvertent entry into the treatment room and the consequent automatic interruption of the treatment.

Conventional x-ray therapy

(124)* Every x-ray tube used for conventional x-ray therapy shall be enclosed in a housing such that, at every specified rating of that tube in that housing, the exposure *rate* from the leakage radiation measured at a distance of one metre from the focus does not exceed 1 R/h, nor 30 R/h at any position accessible to the patient at a distance of 5 cm from the surface of the housing or its accessory equipment. (For the areas over which these measurements shall be made, see paragraph 40.)

(125)* Means (control settings or meters) at the control panel shall be provided to indicate tube potential and current when these can be varied, and for quick recognition of the filtration being used. Whenever practicable, equipment which provides pre-set combinations of tube potential, current and filter should be employed.

(126)* Permanent diaphragms or cones shall be so constructed that, in combination with the tube housing, they comply with the exposure requirements for leakage radiation as given in paragraph 124. Additional cones or adjustable diaphragms should be constructed so as to reduce the integral dose to the patient as much as practicable. They should not transmit more than 2 per cent of the useful beam and shall not transmit more than 5 per cent. Where cones are not used, the diaphragm shall provide a light beam.

(127)* Unless it is possible to bring the x-ray output to the prescribed value sufficiently rapidly that the treatment is not impaired, the tube housing shall be fitted with a shutter, electrically operated from the control panel and complying with the exposure requirements for leakage radiation as given in paragraph 124. The position of the shutter shall be indicated at the control panel by a reliable system, and operation of the shutter shall be independent of the orientation of the tube housing. Such a shutter system shall be checked for correct operation at frequent and regular intervals. When such a shutter system is employed, the automatic timer (see paragraph 70) shall not commence operation until the shutter is open.

(128)* In order to ensure that the prescribed dose is delivered, the equipment shall be provided with an automatic timer which will terminate the exposure by de-energizing the x-ray tube after the pre-set time has elapsed. A transmission monitoring chamber shall be positioned in the useful beam to provide a continuous check on the constancy of the radiation output. In view of the potentially serious consequences resulting from giving a dose in excess of, or less than, that prescribed, the monitoring chamber should also be employed as an integrating meter capable of terminating the exposure after a pre-set value has been reached. The chamber shall be positioned on the patient side of any tube filter employed. The timer and the integrating meter shall preserve their accumulated response in the event of any failure or interruption in the operation of the equipment during treatment.

Superficial x-ray therapy

(129)* The housing of tubes designed for superficial x-ray therapy shall conform to the requirements given in paragraph 124, except for tubes intended to operate at potentials within the range 5–50 kV which shall be provided with a special tube housing such that, at every specified rating of the tube in that housing, the exposure *rate* from the leakage radiation does not exceed 100 mR/h at any position 5 cm from the tube housing or its accessory equipment.

(130) For treatment at potentials up to 50 kV it is permissible for the operator and other essential persons to remain in the room, subject to the provisions of paragraph 131, and provided that the tube housing is of the special type referred to in that paragraph.

(131) The x-ray tube may be held by hand if its housing meets the special requirements of paragraph 129 and if it is fitted with a shield which protects the person holding the tube from exposure to radiation scattered from the patient. Holding of the tube by hand shall only be done when clinically necessary. The person holding the tube shall wear protective gloves and a coat or apron having a lead equivalent of not less than 0.25 mm.

(132)* Due to the low inherent filtration and short focus–window distance, the exposure rate close to the window of a low-voltage tube used for superficial therapy is very high, and even brief exposure to the radiation beam may cause serious injury. For this reason special care is necessary to avoid accidental exposure. An audible signal or a warning light prominently mounted on the housing shall be provided for any tube that may be held by hand, in order to indicate when the tube is energized. When practicable, a cap of at least 0.5 mm lead equivalent shall be fitted over the tube window when the tube is not in use.

(133)* Superficial x-ray therapy equipment shall be so designed as to prevent unintentional combinations of tube potential and filtration. The provisions of paragraph 125 should apply.

"Megavolt" x-ray and particle beam therapy

(134) The appropriate provisions of paragraphs 125 and 128 shall apply.

(135)* The housing of conventional megavolt equipment shall be so designed that the dose rate of the leakage radiation measured at one metre from the source does not exceed 0.1 per cent of the dose rate of the useful beam at that distance. In the application of new techniques or equipment, e.g. neutron therapy, this requirement may not be practicable. In such circumstances, special consideration shall be given to the protection of the patient.

(136)* Permanent diaphragms or cones shall be so constructed that, in combination with the tube housing, they comply with the requirements for leakage radiation as given in paragraph 135. Additional cones or adjustable diaphragms should be constructed so as to reduce the integral dose to the patient as much as practicable. They shall not transmit more than 2 per cent of the useful beam. Where cones are not used, the diaphragm shall provide a light beam.

(137)* Special consideration shall be given to the design of machines capable of emitting either x-ray or electron beams, in order to ensure that the electron beam cannot be emitted inadvertently when an x-ray beam is required.

(138)* Where equipment is capable of delivering dose rates greater than 100 rads/min in air at a distance of one metre, a

completely independent integrating dose meter system shall be employed, in addition to what is required in paragraph 128. This second system shall also be capable of terminating the exposure when a pre-set dose has been given.

Sealed source beam therapy

(139)* Every sealed γ-ray source used for beam therapy shall be enclosed in a housing such that, with the beam control mechanism in the OFF position, the exposure *rate* from the leakage radiation measured at a distance of one metre from the source does not exceed 2 mR/h. At any readily accessible position 5 cm from the surface of the housing, the exposure rate from the leakage radiation shall not exceed 20 mR/h unless the useful beam exposure rate is less than 100 R/h at one metre from the source, in which case the exposure rate from the leakage radiation shall not exceed 40 mR/h. (For the areas over which these measurements shall be made, see paragraph 40.)

(140)* With the beam control mechanism in the ON position, the exposure *rate* from the leakage radiation measured at a distance of one metre from the source shall not exceed either 1 R/h or 0.1 per cent of the useful beam exposure rate at one metre from the source, whichever is the greater. When the useful beam exposure rate is less than 100 R/h at one metre from the source, the exposure rate from the leakage radiation shall not exceed 1 per cent of the useful beam exposure rate.

(141)* Permanent diaphragms or cones shall afford the same degree of protection as the source housing. Additional cones or adjustable diaphragms shall be constructed so as to reduce the integral dose to the patient as much as practicable. In no case shall they transmit more than 2 per cent of the useful beam. Where cones are not used, the diaphragm shall provide a light beam.

(142)* Where the useful beam exposure rate exceeds 100 R/h at a source distance of one metre, the beam control mechanism shall be such that it will automatically return to the OFF position at the end of an exposure or in the event of any breakdown or interruption of the activating force. The OFF position shall be maintained until the mechanism is operated from the control panel. Additionally, the apparatus shall be so constructed that, in case of failure of the automatic return system, the exposure can be interrupted by other means, e.g. manually, in order to protect the patient and to make it possible to unload or repair the treatment head without exceeding the dose limits for planned special exposures (see paragraphs 66 and 67 of ref. 9).

Non-collimated sealed source therapy

(143) A separate room or designated area shall be provided for the preparation of sources and applicators. During such preparation only those persons engaged in the work shall be allowed in the area and eating, smoking, and drinking and the application of cosmetics shall be prohibited.

(144)* In addition to the requirements of paragraph 54, the identification of needles and capsules of the same appearance but of different activity or nuclide should be facilitated during treatment, by such means as coloured beads or threads.

(145) The preparation, sterilization, dismantling and cleaning of applicators and sources involve manipulations with incomplete shielding. Proper tools shall therefore be used to ensure the minimum practicable irradiation of the body. These tools shall be constructed so as to provide the optimum relation between distance and time. Dummy capsules, clearly identifiable as such, shall be used until a high degree of skill has been achieved. Sealed sources shall never be picked up with the fingers.

(146)* Both ambulatory and bed patients containing sealed radioactive sources should be segregated into rooms or wards where properly trained personnel are available. The bed and the room or ward shall be suitably identified when occupied by such patients.

(147)* The number and position of removable sealed sources in or on the patient shall be checked during treatment. Dressings from patients receiving treatment with sealed sources shall not be destroyed until it has been ascertained that they do not contain any sources. After removal of the sources from the patient, all sources shall be accounted for and, in addition, the patient and his dressing

shall be monitored as an additional precaution.

(148)* Patients with removable sealed sources containing material of radioactive half-life greater than 5 days in or upon their bodies should not be permitted to leave the hospital. For the conditions applicable to patients receiving treatment with sealed sources with half-life shorter than 5 days, see ICRP Publication 5 (ref. 5).

Therapy with unsealed sources

(149) Recommendations on protection against exposure from unsealed sources and on the discharge of patients are given in ICRP Publication 5 (ref. 5).

Protection of the patient

Introduction

(150) This section is concerned with medical exposures in the same sense as defined in paragraph 32 of ICRP Publication 9 (ref. 9). For the purpose of the following recommendations, and in order to include all types of diagnostic and therapeutic exposure to ionizing radiation, the term "medical exposure" is therefore extended to apply to all types of exposure of patients administered by radiologists, other medical practitioners including obstetricians and general practitioners, dentists, osteopaths, chiropractors, etc.

(151) A number of the recommendations in the previous section of the chapter on medical uses of radiation are also aimed at reduction of the radiation dose to the patient. These paragraphs have been marked with an asterisk. The following paragraphs mainly deal with protection aspects which are less directly related to equipment. Although no guidance is given with regard to the best methods of diagnosis or treatment, recommendations are given on various aspects of the operational procedures. It is important that those who use radiation on patients keep abreast of technological and clinical developments in respect to the methods.

(152) The dose limitations recommended by ICRP (ref. 9) relate to radiation exposures other than those received by the patient in the course of medical procedures or from natural background radiation. On the assumption that the frequency of harmful effects is proportional to the dose received, each increment of dose will correspond to a resulting increment of the risk of such effects. The appropriate limitations on the contributions to the total dose received from occupational and medical exposures can and should then be considered separately, in the light of the importance of these types of exposure. A particular radiological procedure would not be justified unless the associated risk is offset by the medical benefit expected to accrue to the individual or to the population. It is therefore not appropriate to give any predetermined, generally applicable dose limitations, and the ideal judgement of what should be considered to be an acceptable dose would have to be based upon the known circumstances in each case, including the consideration of alternative techniques that may permit a dose reduction.

(153) When the probability of a harmful effect cannot be assumed to be proportional to the radiation dose—e.g. at high doses which may produce acute radiation injury—the risk from a certain medical exposure is not determined solely by the resulting dose but is also influenced by previous high exposures, irrespective of source. In such cases, the *total* radiation dose in the relevant organs and tissues, and the time over which it has been received, must be taken into consideration.

(154) The risk of certain harmful effects at low doses of radiation was estimated in ICRP Publication 8 (ref. 8), on the assumption that the expected number of cases in an exposed population per unit dose is the same at very low doses as that observed at the considerably higher doses for which reasonably quantitative observation is possible. The values enunciated in that report were thus considered to represent *upper* limits of the risk.

(155) Theoretically, it should be possible to balance the expected need or benefit of the exposure against the risk imposed by the irradiation. In practice, this is not possible with regard to individual patients, except at high doses in radiation therapy. For most types of x-ray diagnostic examinations, how-

ever, the radiation dose and the most pessimistic estimate of the related risk are so low for properly considered and conducted examinations that any detailed consideration of benefit–risk is unnecessary in individual cases.

(156) Provided that a certain diagnostic *procedure* as such is generally considered justified because the medical benefit to the patients is believed to outweigh the risk from the exposure, the remaining judgement in the *individual* case would relate to the choice of x-ray examination as being appropriate for that individual, the conduct of the examination and the interpretation of the result. If any one of these three actions is impaired by ignorance, negligence or lack of resources, the radiation exposure may still be justified from the point of view of the diagnostic information but the diagnostic yield has then been obtained at an unnecessarily high cost in terms of radiation dose and corresponding risk.

(157) The decision as to whether a certain radiation dose to a patient is justified is sometimes the responsibility of the referring physician, sometimes of the radiologist. In either case, however, it is imperative that the decision is based upon a correct assessment of the indications for the examination, the expected yield from the examination and the way in which the results are likely to influence the diagnosis and subsequent medical care of the patient. It is equally important that this assessment is made against a background of adequate knowledge of the physical properties and the biological effects of ionizing radiation.

(158) No person shall operate radiological equipment without adequate technical competence nor apply radiological procedures without adequate knowledge of the physical properties and harmful effects of ionizing radiation.

(159) The curriculum for medical students should include at least the foundation that is necessary for an understanding of the basic aspects of radiation protection, particularly with regard to the elements necessary in the exercise of good clinical judgement. Since most physicians are likely to become involved in some decisions implying irradiation of patients, more extensive training in radiation fundamentals, including protection, would be valuable for all medical students.

(160) A special ICRP report (ref. 15) deals with the elements of education and experience necessary for the exercise of sound judgement in the clinical, administrative and technical aspects of diagnostic radiology. This report should be included in the course material for medical students and in postgraduate courses where appropriate.

(161) Protective measures in the widest sense include good clinical judgement and proper design of radiation sources and protective equipment as well as good operational practice and competent interpretation of the diagnostic information.

(162) Good clinical judgement implies that no patient is exposed unnecessarily as far as can be judged when the exposure is decided. It is therefore important that all relevant clinical information, including previous radiological data, is studied and that alternative techniques are considered before examinations or treatments with radiation are requested or initiated. It is, however, equally important that necessary examinations or treatments are not withheld because of a radiation risk which, in the majority of diagnostic cases, is very low.

(163) Once a technique of radiological examination or treatment has been chosen, it shall be applied with the minimum patient exposure consistent with securing the desired diagnostic information or therapeutic result.

(164) Due to lack of comprehension, the interpretation of recommendations on protection of the patient has, on occasions, caused unwarranted alarm and has therefore led some patients to hesitate in seeking necessary medical attention. Every effort should be made to give the public a sound view of the magnitude of the radiation risks and of the general benefit from and need for various types of diagnostic and therapeutic irradiations.

(165) The following recommendations on the protection of the patient relate to operational procedures. The recommendations are limited to the various types of *external* exposures even though a number of the general statements in the previous paragraphs would naturally apply also to the use of radioactive substances as *internal emitters*. The recommendations mainly relate to x-ray diagnostic procedures.

Recommendations with regard to operational procedures

General

(166) The basic protective requirement is that the radiation dose to the patient, especially the integral dose and the dose to the gonads and the active bone marrow, shall not be greater than necessary to obtain the relevant diagnostic information or to produce the desired therapeutic result. In general, the most effective way of ensuring this is by limiting the field size.

(167) The patient dose is also influenced by quantities and parameters such as radiation quality (kV, filtration), sensitivity of the recording system, beam direction and source–skin distance. An assessment of this influence in diagnostic radiology is given in the ICRP report on the protection of the patient (ref. 15).

(168) Particular care should be exercised when the patient's gonads are within or near the useful beam or when a foetus may become irradiated. If the patient's gonads must be within the limits of the beam, but do not actually need to be exposed, they should be shielded.

(169) Particular attention shall be given to filters that will prevent non-useful low-energy radiation from reaching the patient and unnecessarily increasing the dose. It should be recognized that this radiation may not only be harmful to the patient but may also reduce the quality of the image in x-ray diagnostic work; it will usually limit the total tumour dose that can be delivered in deep therapy. Specific recommendations on filtration for diagnostic equipment are given in paragraph 78.

(170) Medical exposure of humans shall never occur as the result of administrative decisions, e.g. for legal purposes, without due consideration of the relevant medical data and the need for the examination or treatment in each individual case.

(171) Special precautions shall be taken with regard to the protection of patients awaiting examination or treatment. Waiting-rooms with adequate protection shall be available, and any exposure which is not part of the diagnostic procedure or therapeutic irradiation shall be subject to the limitations that apply to non-medical exposures.

X-ray diagnosis

(172) All diagnostic x-ray work shall be performed with the most appropriate combination of operating potential, filtration, focal–skin distance, field limitation and recording medium (see also paragraph 167). Guidance on the choice of these factors is given in the special report on the protection of the patient (ref. 15). *Minimum* requirements on filtration and focal–skin distance are given in paragraphs 78 and 92, respectively.

(173) It is of primary importance to decide on the minimum field size in relation to the size of the region of interest. The field size may be smaller than but, with the exception of intraoral dental radiography, shall in no case be larger than the size of the film or screen to be used. Apart from this exception, the proper limitation of the field to the area of interest should be demonstrable on the film.

(174) The ICRP has for a number of years called attention to the embryonic and foetal sensitivity to ionizing radiation. The possibility of pregnancy must be taken into account by the attending physician when deciding on examinations that involve the lower abdomen and pelvis of women of reproductive capacity. The Commission has pointed out that the 10-day interval following the onset of menstruation is the time when it is most improbable that such women could be pregnant. Therefore, it is recommended that all radiological examinations of the lower abdomen and pelvis of women of reproductive capacity that are not of importance in connection with the immediate illness of the patient, be limited in time to this period when pregnancy is improbable. *The examinations that it will be appropriate to delay until the onset of the next menstruation are the few that could without detriment be postponed until the conclusion of a pregnancy* or at least until its latter half.

(175) While pelvimetry is sometimes of great value, it should be undertaken only on the rare occasions when this is likely to be so and should never be carried out on a routine basis.

Fluoroscopy

(176) In general, fluoroscopy should only be used when radiography is not expected to

provide the required information, e.g. in some dynamic studies or when the time element is of importance. Image intensifiers should be used with the aim of reducing the patient's dose and increasing the information content of the examination.

(177) The exposure rate for direct fluoroscopy as measured at the patient entrance surface shall be as low as practicable and should not exceed 5 R/min.

(178) A transmission monitoring chamber in the useful beam may be used for observing the radiation output. Such a chamber should be arranged to measure the product of field size and either exposure or energy fluence. This is of particular value in fluoroscopy, in training operators to restrict to the minimum both x-ray beam size and fluoroscopic time.

(179) Before a direct fluoroscopic examination is begun, the eyes shall be sufficiently dark-adapted. In order to enable work with the lowest possible exposure rate, the adaptation period should be at least 10 minutes (see paragraph 101).

(180) Where direct fluoroscopy cannot be avoided in chest examinations, it shall be performed at tube potentials of 80–100 kV, a filtration equivalent to at least 4 mm Al, a tube current not exceeding 2 mA, and a focus–skin distance not less than 60 cm.

Radiography

(181) Screen-type film is less sensitive to direct x radiation than non-screen film and should therefore not be used for non-screen techniques.

(182) When the highest definition is not essential, a high-speed film-screen combination shall be used in order to reduce the patient dose.

(183) Special precautions shall be taken in order to make retakes of radiographs unnecessary. For example, the operating conditions shall be checked before the exposure is made, and care shall be taken that the patient is correctly positioned and immobilized.

(184) Technicians and radiographers should see their films after processing, since this enables techniques to be adjusted to produce films of optimum diagnostic value for minimum patient dose.

(185) It is particularly important to avoid re-taking a long series of films. To ensure that correct radiographic settings are used, a single preliminary film should be exposed and processed before the main series is taken.

(186) Care should be taken to prevent fogging of the film. Fogging may be caused by an unsatisfactory darkroom safe-light, by scattered radiation in the x-ray room or by x rays from unexpected sources such as rectifying valves in a high tension generator cabinet. Unavoidable fogging is caused by the natural radiation background, but this may be reduced if particularly radioactive building material is avoided and if film storage time is limited.

(187) Good processing techniques are essential also for the protection of the patient. It is important not to use a technique which involves overexposure and subsequent underdevelopment of the film. Normal development should enable a medium speed film, with medium speed screens, when exposed to about 1 mR, to have an acceptable density for diagnostic purposes (average density about 1.0).

(188) The correct developer and fixer should be selected for the types of film to be used and for the processing temperature. Routine control of film density by inspection during development is strongly deprecated. The density should be controlled by time and temperature in a consistent technique. The developer shall be replenished as necessary and replaced at regular intervals; during development, it shall be subject to the correct amount of agitation. The content of the fixing bath should be strictly confined. If washing is carried out in running water, this should preferably be at about the same temperature as the processing solutions. Drying should be carried out in a special cabinet.

(189) Where there is a sufficient throughput of films to ensure correct use and to justify the expense involved, automatic processing machines should be used as they facilitate compliance with most of the recommendations in paragraphs 187 and 188.

(190) The dark-room shall be adequately light-proof: it should not be possible to see any light from outside after twenty minutes dark-adaptation from daylight. It is essential to use the correct safe-lights, including correct filters, bulb power and fittings.

(191) Mass examinations should not be initiated unless the expected yield, the radiation risks, and the availability of ade-

quate follow-up of positive cases, have been evaluated. Fluoroscopy shall not be used for such examinations.

Dental radiography

(192) Standard x-ray equipment designed for dental radiography shall not be used for other radiographic work (see paragraph 38). If panoramic dental radiographs or other special projections are needed, the necessary specialized equipment shall be employed (see paragraph 114).

RADIOTHERAPY

(193) In addition to paragraphs 166–171, the following paragraphs in the previous sections specifically relate to protection of the patient in radiotherapy: 122–129, 132, 133, 135–142, 144 and 146–148.

Medical research

(194) In special circumstances of medical research involving new procedures, the recommendations in this chapter may be unreasonably restrictive. A review of each such procedure shall, however, be conducted by an appropriate and designated group of qualified experts. Reference is made to more general statements on medical research, such as the Declaration of Helsinki (ref. 19). Guidance with regard to experimental irradiations which are entirely unrelated to the patient's illness is given in paragraph 278.

VETERINARY USES OF RADIATION

General requirements

(195) This section of the report deals with the diagnostic and therapeutic uses of ionizing radiations for veterinary purposes. Most of these uses involve external radiations only but, for the sake of completeness, reference is also made to the use of sealed and unsealed radioactive materials.

(196) In general, the equipment and procedures employed in veterinary radiology are similar to those used in medical radiology and, in consequence, broadly similar protection measures are necessary. This section of the report is therefore limited to recommendations which deal with the special protection problems that arise in veterinary work and persons who are engaged in or are responsible for such work are also referred to the General Recommendations (paragraphs 20–66) and to paragraphs 67–149 which deal with the corresponding medical activities.

(197) It is often found that the x-ray equipment at present used for veterinary purposes is obsolete, that the working conditions are unsatisfactory and that the persons undertaking the work are less well trained in radiological procedures than are their medical counterparts. In addition, the problems of animal immobilization are much greater than those that arise in the corresponding aspects of medical radiology. For all these reasons it will often not be possible to regard veterinary radiology as providing "conditions such that the resulting doses are most unlikely to exceed 3/10 of the annual Maximum Permissible Doses", and the recommendations of paragraphs 110–113 of ICRP Publication 9 (ref. 9) should be applied accordingly.

X-ray diagnosis

(198) A radiological examination should only be undertaken if there is a definite clinical indication for the use of the procedure. It should be noted that veterinary uses of radiation provide less justification for "planned special exposure" (paragraphs 66–67 of ICRP Publication 9) than do the corresponding medical uses.

(199) For reasons similar to those that apply in medical x-ray diagnosis, radiography

is normally to be preferred to fluoroscopy, the use of which should be confined to those examinations, e.g. the study of movement, which cannot satisfactorily be performed by radiography.

(200) Wherever practicable, diagnostic procedures on the premises of a veterinary radiologist should be undertaken in a room that satisfies the recommendations for similar medical work. When, for example, the size of an animal makes it impracticable for it to be examined in the room, the examination should take place in a special controlled area which has been selected for the purpose, from which unnecessary persons can be excluded, and in which the examination can be conducted under conditions that provide adequate protection for all persons, including any in adjacent buildings and passers-by. In the case of examinations that are undertaken away from the premises, special care should be taken to ensure that adequate protection is afforded to all such persons.

(201) Whenever practicable, a table should be used for radiography. Unless the table is specially equipped for radiographic purposes, the film or film cassette shall be placed on a sheet of lead at least 1 mm thick and of sufficient area fully to intercept the x-ray beam.

(202) Whenever radiography with an angulated or horizontal beam is necessary, the film or film cassette shall be supported by mechanical means. Long-handled cassette holders should be available for this type of work and particularly for large animal radiography (see paragraph 207).

(203) No person shall remain in an x-ray room when radiological procedures are being carried out unless his presence is essential. The tube housing shall not be held by hand during exposure. The so-called "hand fluoroscope" or "head fluoroscope" shall not be used.

(204) In addition to conventional protective clothing (paragraphs 98 and 99), sheets of lead rubber or other flexible protective material suitable for hand or forearm drapes should be available for all persons who may be required to hold animals during examinations. The lead equivalent of such drapes shall be not less than 0.25 mm for use with x-ray equipment capable of operating up to 150 kV.

(205) The animal shall not be held by hand unless other means of immobilization are impracticable. Such means may be mechanical or, together with suitable positioning aids, tranquillization or anaesthesia.

(206) When manual immobilization is necessary:

(a) the animal shall be held by the minimum number of persons necessary to immobilize it, while allowing each person to position himself as far as practicable from the path of the useful beam;

(b) those holding the animal shall wear protective gloves and aprons and, if practicable, use drapes (see paragraph 204), ensuring that no part of their bodies, even if covered by protective clothing, is in the path of the useful beam;

(c) as far as practicable, the animal should be held by persons unlikely to be occupationally exposed to ionizing radiations, for example, the owners, providing they are not under the age of 18 years or are pregnant;

(d) if it is necessary for members of the staff to hold animals, a rotation system should be employed which should not include persons under the age of 18 years or pregnant women, and the doses received by the hands and forearms during such examinations should be measured as required by the competent authority.

(207) The examination of large animals, e.g. horses and cattle, creates particularly difficult problems because it is seldom practicable to anaesthetize the animal, and manual restraint is therefore almost certain to be required, although the problems involved will be considerably eased if suitable tranquillization is achieved. In addition, it is often necessary for the useful beam to be directed horizontally, which means that the film or film cassette needs to be supported, with the consequent increase in the risk that assistants and other persons will be irradiated. Furthermore, those restraining the animal or assisting in supporting the film cassette are likely to have their attention concentrated on their tasks rather than on avoiding the useful beam. Finally, if the examination of parts other than

the lower limbs is required, the exposure factors may need to be considerably increased. Because of these possibilities of excessive exposure, those responsible for the examination should be particularly careful to ensure that all concerned are adequately protected.

(208) For fluoroscopic examinations, image intensification systems should be used as they can lead to significant reductions in the exposure of those involved. Subdued room lighting should be employed during the examinations (see paragraph 101).

(209) Fluoroscopic equipment shall be constructed in accordance with paragraphs 86 and 87, and the useful beam shall always be intercepted by a barrier having a lead equivalent of not less than:

1.5 mm for apparatus having a maximum operating potential up to and including 70 kV;
2.0 mm for apparatus having a maximum operating potential above 70 kV up to and including 100 kV;
an additional 0.01 mm per kV above 100 kV.

(210) Manipulation of the animal during fluoroscopy should be restricted to the shortest possible time and never be undertaken unless protective gloves are worn. The doses received by the hands and forearms during such manipulation should be measured as required by the competent authority.

Radiotherapy using x rays and sealed radioactive sources

(211) Radiotherapy shall be performed only under the close supervision of veterinary or medical personnel trained and experienced in such procedures. The apparatus, procedures and protection measures employed shall be similar to those used for medical radiotherapy.

(212) In the treatment of animals by means of sealed radioactive sources that are applied to or inserted into them, particular care shall be taken to safeguard the sources against damage, to confine the animals to the premises during the period of treatment and to provide adequate protection for all persons.

The use of unsealed radioactive substances

(213) Unsealed radioactive materials shall be used only under the close supervision of suitably trained and experienced veterinary or medical personnel. The advice of a suitably qualified physicist should be available, and ancillary staff should also have had appropriate training.

(214) Premises and equipment used for diagnostic and therapeutic uses of unsealed radioactive materials shall be designed to ensure the safe handling, containment and storage of the radioactive material and to minimize the difficulties of decontamination, should this become necessary. The appropriate recommendations of ICRP Publication 5 (ref. 5) shall be put into effect in order to achieve these objectives.

(215) Consideration shall be given to the safe transport and disposal of radioactive materials, to the management and disposal of animals to which radioactive materials have been administered, to the disposal of excreta and other contaminated materials and to the control of food products intended for human use. In all these respects it will be necessary to conform to such control measures as may have been laid down by the national competent authorities.

INDUSTRIAL USES OF RADIATION

General requirements

(216) The general requirements given in paragraphs 20–66 shall also apply, where appropriate, to the industrial uses of radiation. In addition, the following sections give more specific recommendations relating to such uses.

Industrial radiography

(217) In establishing the extent of a controlled area (see paragraph 20:113), consideration shall be given to the protection of persons who work above the level of the installation (e.g. crane operators and repairmen). As an example, interlocks may be provided to limit crane operation to locations where a radiation survey indicates adequate protection of the operator.

(218) Whenever practicable, industrial radiography should be carried out in enclosed installations.

(219) An *enclosed installation* is one in which the radiation source and all objects exposed thereto are within a permanent enclosure which prevents people from entering it and from remaining within it during the irradiation and which affords, under all operating conditions, adequate protection for all persons at approved locations outside it.

(220) An *open installation* is one in which the radiation source and all objects exposed thereto are within an area to which only authorized persons have access but in which they shall not remain during the irradiation and outside which, under all operating conditions, adequate protection is afforded to all persons.

Enclosed installations

(221) Audible and/or visual warning signs shall be provided within the enclosed installation. These signs shall be actuated before the irradiation begins and shall remain actuated until completion of the irradiation.

(222) Reliable locks or interlocks shall be provided to prevent any person from entering a radiation room during irradiation. In the event of an exposure being terminated by an interlock, it shall only be possible to reinitiate the irradiation from the control panel.

(223) Suitable means of exit shall be provided, so that any person who is shut in the irradiation room by accident can leave the enclosure without delay.

(224) Where practicable, effective means, that cannot be reset from outside, shall be provided within the enclosure for preventing or quickly interrupting the irradiation. The means provided should, if possible, not be located in an area subject to the radiation beam.

Open installations

(225) Means shall be provided to prevent the access of unauthorized persons to open installations. For example, temporary barriers, consisting of fencing or rope, may be used. Appropriate warning signs and lights shall be prominently displayed.

(226) Where distance protection is not practicable, effective shielding shall be provided. For this purpose, the use of readily demountable and reusable barrier materials may present economic advantages. Where barrier sections are removed to permit entry and removal of objects, special attention shall be given to their correct replacement.

(227) Particular attention shall be paid to the protection of the operator, for whom an adequately shielded control box or protective screens should be provided when adequate distance protection is not practicable.

(228) Before an open installation is used, it shall be verified that adequate protection is provided. A knowledgeable person shall be in attendance during every irradiation.

(229) Equipment used in open installations shall be locked in the OFF condition when not in use, i.e. when permanently or temporarily stored and during transport. When in use, i.e. during manipulations and exposure, the equipment shall be under continuous supervision. Special care should be taken to secure sealed radioactive sources against unauthorized removal.

X rays

(230) With the exception of the equipment mentioned in paragraph 231, every x-ray source used for industrial purposes shall be enclosed in a housing such that the exposure from the leakage radiation measured at a distance of one metre from the source does not exceed one roentgen in one hour at every specified rating of that source in that housing.

(231) Exceptions from the requirement of paragraph 230 are permitted for "megavolt"

x-ray equipment when used in enclosed installations. In such cases, however, the dose rate of the leakage radiation, measured at a distance of one metre from the source, shall not exceed 0.1 per cent of the dose rate of the useful beam at that distance.

γ rays

(232) Industrial γ-radiography is performed with a variety of sources and under widely differing conditions. The following recommendations are aimed at specifying the basic protection requirements, irrespective of the actual technical arrangements in each individual case.

(233) Protection needs to be provided for several stages in the work, viz. the long-term storage of the source, local transport and manipulation, temporary storage between exposures, and the actual irradiation. The recommendations concerning the identification of sources, given in paragraph 54, are particularly applicable to industrial radiography.

Long-term storage

(234) The sources may be stored for long periods either in the same containers that are used during local transport and temporary storage between exposures, or in special containers for the purpose, including shielded safes, or holes in the ground.

(235) When stored for long periods, radioactive sources intended for γ-radiography shall be provided with sufficient shielding to ensure adequate protection for all persons (see paragraph 60). Under no circumstances shall the exposure rate from the leakage radiation outside the store exceed 2 mR/h at a distance of one metre from the source, nor shall the exposure rate of the leakage radiation exceed 20 mR/h at any readily accessible position 5 cm from the outer surface of the protective container or any additional shielding used around it during long-term storage (see paragraph 40). If the store is located outside the controlled area, it may be necessary to reduce these exposure rates.

(236) One type of store for long-term storage for industrial radiographic purposes is the industrial protective source housing referred to in ICRP Publication 3 (ref. 3). Such a housing shall be so constructed that, with the beam control mechanism in the OFF position, the exposure rate of the leakage radiation will not exceed the values specified in paragraph 235.

Temporary storage

(237) During local transport and temporary storage between exposures it is, in some applications, not practicable to provide the same degree of shielding as is required for permanent stores. During such operations the sources should normally be so shielded that the exposure rate of the leakage radiation at a distance of one metre from the source does not exceed the value given in paragraph 235, while the exposure rate at 5 cm from the surface of the protective container should be permitted to be up to ten times the corresponding value in paragraph 235, i.e. it should not exceed 200 mR/h.

(238) Where the circumstances of the work do not allow housings to conform to the requirements of paragraph 237, the necessary precautions shall be taken to ensure that overexposure of persons will not occur. Such precautions may involve limitation of the working time in the vicinity of the source and/or modifications to working procedures. The implementation of the extra safety measures shall be supervised by a responsible person. The competent authority shall be informed of the special problems, and no use of a protective arrangement not meeting the requirements of paragraph 237 should be permitted unless authorized by the authority.

(239) Containers used for local transport or temporary storage of radioactive sources should be:

(a) permanently marked for the intended use (nuclides, maximum permitted activities);
(b) permanently marked with a warning if they do not fulfil the requirements for permanent storage (see paragraph 235);
(c) temporarily marked with a label indicating the actual use of the container (nuclide, activity).

Handling and use

(240) During irradiation, the source may either remain in the protective container used for temporary (or long-term) storage or it

may be removed from it. Where the source remains within the container, and a change in the shielding conditions occurs between the OFF and the ON positions, the exposure rate of the leakage radiation at a distance of one metre from the source, in the ON position, should be marked on the container for specified activities of given nuclides.

(241) The manipulation of sources outside the protective containers shall only be carried out by persons who have been adequately trained, particularly with regard to source security and operational procedures (see paragraphs 53–66). The radiographic arrangement shall be completed before the sealed source is brought into the irradiation position.

Industrial fluoroscopy

(242) Fluoroscopic equipment shall be so designed that the x-ray tube and all objects exposed to the x rays are totally and permanently contained in an enclosure that provides adequate protection to all persons. The enclosure shall be fitted with interlocks which prevent access to its interior during irradiation. In the event of an exposure being terminated by the interlock, it shall only be possible to reinitiate the irradiation from the control panel.

(243) In assessing the shielding requirements, attention should be paid to paragraph 26. It should be noted that tube housings of the type specified in paragraph 230 will require additional protection in fluoroscopic installations, even if they are equipped with satisfactory housing for leakage limitation. The requirements on adequate protection can be met even in the total absence of a protective tube housing, but the provision of a "diagnostic" type tube housing will reduce the amount of additional shielding in the enclosure.

(244) Fluoroscopic screens should be viewed indirectly, either by the use of mirrors or remotely by television techniques. When the fluoroscopic screen is viewed directly or by means of mirrors, attention should be paid to the dark-adaptation of the viewer and the light level in the viewing room. Old screens which are found to be much less sensitive than new ones should be replaced. The so-called "hand fluoroscope" or "head fluoroscope" shall not be used.

(245) Care shall be taken to ensure adequate protection for all persons associated with the fluoroscopic procedures, for example those who load articles for examination on to moving belts or trays.

(246) When it is necessary to manipulate or mark objects under examination, provision shall be made for this to be done while still maintaining adequate protection.

Industrial gauges and similar equipment

(247) X-ray, γ-ray, and β-ray thickness gauges, level gauges, static eliminators and similar devices should be housed, shielded and installed so as to prohibit unauthorized access to the devices and so that workers routinely associated with the devices can be considered as being outside a "controlled" area. This will avoid the need for personal monitoring and special medical examinations.

(248) Particular attention should be paid to the instruction of cleaning and maintenance personnel who, in the performance of their duties, may be close to or need to manipulate the radiation source. Wherever practicable the device should be constructed, installed and shielded so that under such circumstances no person can receive doses of more than three-tenths of the appropriate maximum permissible doses.

(249) Means shall be provided to prevent the insertion of parts of the body into the useful beam during normal operation.

X-ray analytical equipment

(250) Equipment of this type is particularly dangerous since the very high exposure rates close to the window of the x-ray tube can cause injury after very brief exposure. In recent years a number of accidents has occurred which have resulted in severe injuries to personnel.

(251) The term analytical x-ray equipment

is used here to include all types of x-ray diffraction and spectrographic equipment. Whenever appropriate the recommendations of paragraphs 20–47 shall be put into effect.

(252) The equipment shall be periodically monitored. Most types of dose-measuring equipment have an inadequate response to low-energy x radiation and give misleading readings unless exposed to uniform radiation fields. Such dose-measuring equipment may, therefore, not detect leaks of small cross-section. Defects in shielding may best be detected by means of fluoroscent screens or films, and measured by suitable types of radiation detector having small apertures.

(253) Adequate periodical medical examinations shall be carried out, particular attention being paid to the eyes and to the skin of the hands and face. On account of the nature of the radiation hazards, it should be recognized that conventional examinations (e.g. involving blood counts) and individual monitoring, which is not adapted to the particular conditions prevailing in this kind of work, may give rise to a false sense of security.

(254) Operators of x-ray analytical equipment should use finger or wrist monitoring devices. Suppliers of monitoring devices should be notified of the type and energy of the radiation being monitored. Such monitoring is not necessary in the *routine* operation of fully enclosed units, which provide adequate protection.

(255) In order to permit the x-ray equipment to be switched off (e.g. during maintenance work) without simultaneously switching off auxiliary equipment such as electronic recording devices etc., the high tension generator supplying the x-ray tube shall have an independent and easily disconnectable cable connection (e.g. a plug-in type terminal) or line switch.

(256) *Warning signs,* clearly visible, shall be used as follows:

(a) labels with appropriate warnings shall be placed near any switch that energizes a tube and also at the tube housing;
(b) warning signs shall be placed near the equipment and also, when appropriate, outside the entrance to the room.

(257) *Warning lights* shall be clearly visible and of a reliable type (see paragraph 47). A warning light shall indicate whether the tube is energized. Preference should be given to lights of the flashing type. Such lights should also be used at the entrance of the room during exposure, if the equipment itself does not provide adequate protection.

(258) The condition of each shutter (i.e. whether open or closed) shall be clearly recognizable at or near the tube.

(259) The on–off switch for each x-ray tube shall include a visual indication of the tube status. All indicators shall be of a reliable type.

(260) Unless the equipment fulfils the requirements of paragraph 264, each port of the tube housing shall be provided with a beam shutter so arranged that it can be open only when the emergent radiation is totally enclosed.

(261) The exposure rate at any accessible position at a distance of 5 cm from the outer surface of a totally enclosed equipment, with shutters open or closed, shall not exceed 2.5 mR/h at every specified tube rating (see paragraph 40). Frequently, the outer surface of the equipment will include parts of the tube housing.

(262) An interlocking device should prevent entry of any part of the body into the beam path or cause the beam to be shut off upon such entry into its path.

(263) The x-ray camera or other recording device shall be provided with a protective screen that effectively absorbs the radiation.

(264) When a total enclosure of the equipment is not practicable, it shall be so located and supervised that no person can occupy an area in which there is a higher exposure rate than 2.5 mR/h (see paragraph 40).

(265) Any exceptional manipulations involving potential hazards beyond those expected from routine operations shall only be permitted after special authorization by a competent person on each occasion. If he cannot himself be present during such manipulations he should take steps to ensure that the personnel involved have sufficient instructions to perform their work safely.

(266) Neither repair nor cleaning involving removal of covers, shielding material or tube housings, nor non-routine exchange of filters, shutters, collimators, etc., shall be performed

unless it has been positively ascertained that the tube is de-energized, e.g. through disconnection from the electrical supply line. *It must be recognized that negligence with regard to this simple precaution has caused the majority of the most severe accidents.*

RESEARCH USES OF RADIATION

(267) Many radiation sources that are used in research, e.g. conventional x-ray equipment and sealed radioactive sources, are similar or identical to those used for industrial medical and veterinary applications of radiation, and many of the recommendations given in those sections as well as all the general recommendations also apply to research uses of radiation. However, because of the usually greater flexibility required in the design and operation characteristics of radiation sources for research purposes, special hazards to the operator or personnel in the environment of such sources may occur.

(268) In particular, special radiation protection problems may arise in research installations employing such sources as nuclear reactors, accelerators and sealed sources of high activity. Because of the penetrating radiation emitted by such sources or because of radioactive substances being released into the environment, the exposure of the public merits special consideration. In the planning of installations to house such sources, careful consideration shall be given to the proper siting, design and use, taking into account all relevant factors. Such factors include population density, topography, meteorological conditions, shielding, area restrictions and the consequences of conceivable accidents. The installation shall only be permitted to be erected and operated if it complies with the relevant national and local requirements. Where such requirements are not applicable, advice shall be obtained from the competent authority (see paragraph 20:118).

(269) During the operation of installations of the types under consideration, the recommendations of paragraph 20:109 shall be applied. Particularly in the case of research reactors, plans for an emergency warning system for the evacuation of the installation and its environment and for the work of specially trained and appropriately equipped emergency teams shall be developed and frequently tested in exercises. In the operation of such reactors, persons competent to deal with any accident or emergency shall be on duty or be readily available.

(270) A record shall be kept, indicating the operating conditions and the times of operation of large radiation sources.

(271) Hydrogen-containing materials are usually the most practical neutron shields. Water, concrete, hydrocarbons and plastics are good neutron moderators. Addition of thermal neutron absorbers such as boron compounds (B_2O_3, B_4C) to the shielding material further improves its shielding properties. Concrete is convenient both for constructional reasons and because of its γ-ray shielding properties. For neutron energies above 5 MeV, the use of high density shielding materials, such as steel, between the source and the hydrogeneous material should be considered (see Appendix 9 of the supplement to this report).

(272) Stray radiation of unexpected origin and direction may present protection problems when an accelerator is not operated under ideal conditions. Problems may also be caused by induced activity (see paragraphs 49 and 302).

(273) The choice of proper instruments for radiation measurements is particularly important under conditions where unusual types of radiation may be present. In the vicinity of pulsed radiation sources, the high dose-rate dependence of some ionization chambers will lead to serious underestimations of doses or dose-rates.

(274) In the case of neutron generators using tritium targets, tritium contamination of the vacuum system and of the exhaust air may be a potential health hazard, independent of the radiation output of the machine. Recommendations on protection measures against internal exposures are given in ICRP Publication 5 (ref. 5) and advice on monitoring is given in ICRP Publications 10 (ref. 10) and 12 (ref. 12).

(275) Recommendations on protection requirements in the use of x-ray analytical equipment are given in paragraphs 250–266.

When such equipment is used for research purposes, the potential risk is often increased because of the greater variety of applications in the use of each piece of equipment.

(276) In the development of new medical radiological procedures, some of the recommendations of paragraphs 67–193 may be unduly restrictive. In such situations, particular care should be given to ensuring that only knowledgeable and highly competent personnel carry out the procedure. The hazard involved should be appraised, and the exposure of both the personnel and the patient or volunteer shall be under constant review.

(277) Reference to the problems relating to the exposure of patients in clinical research is given in paragraph 194.

(278) The deliberate irradiation of persons for the purposes of research and other studies, in which no direct benefit to those irradiated is intended and the exposure is entirely unrelated to any illness they may have, should only be undertaken by properly qualified and trained persons. Such irradiation should only be given with the consent of the authorities in charge of the institution where the irradiation is to take place, as advised by an appropriate expert body and subject to local and national regulations. The estimated risks involved in the irradiation should be explained to those involved, who should be volunteers fully able to exercise their free will. The higher the dose the more rigorous are the requirements on the conditions of securing true volunteers and on their capability of understanding the risk. It follows that the irradiation for the purposes of such studies of children and other persons regarded as being incapable of giving their true consent should only be undertaken if the expected radiation dose is low (e.g. of the order of magnitude of one year's exposure from natural radiation) and if valid approval has been given by those legally responsible for such persons.

(279) Research involving *in vivo* neutron activation analysis on humans should only be carried out after a careful assessment of the radiation protection problems involved.

USE OF RADIATION IN EDUCATION

(280) The Commission has published a special report (ref. 13) that deals with the use of and exposure to sources of ionizing radiations in general science courses in schools. Special dose limits are recommended in that report for such uses and it is emphasized that the curricula must include appropriate instruction in radiation protection.

(281) All other uses of radiation in education, for example in training for particular types of work such as medical or industrial radiology or radiography, shall be undertaken in accordance with the recommendations of appropriate sections of this report and with due regard to the other publications of the Commission, particularly ICRP Publication 9 (ref. 9). In all such training, adequate instruction in the principles and practice of radiation protection shall be given. In training for medical uses, additional emphasis shall be given to the protection of the patient, and the attention of students should also be drawn to ICRP Publication 16 (ref. 15).

MISCELLANEOUS SOURCES AND USES OF RADIATION

(282) In every case of a source or use of radiation that is not dealt with elsewhere in this report, the same general principles of radiation protection as have already been stated should be applied to an appropriate extent. For example, in x-ray microscopy or in installations for the irradiation of materials, it is necessary to protect persons against both primary and scattered radiation, and means shall be provided to prevent access to the irradiation area while the apparatus is in use.

(283) The irradiation of food intended for human consumption (for example, in package monitoring or quality control) shall be undertaken in such a manner as to provide adequate protection for all persons, and the doses delivered to the foodstuffs should be limited in accordance with local or national regulations. The latter aspect and also the irradiation of food for sterilization and similar

purposes (e.g. for the inhibition of the sprouting of potatoes) involve important problems not connected with radiation protection. The reader is referred to a report by WHO and FAO (ref. 20).

(284) The use of x rays for shoe-fitting purposes should be limited to necessary medical (orthopaedic) examinations. It is strongly urged that the use of radiation for commercial shoe-fitting purposes be prohibited.

(285) The irradiation of persons for non-medical purposes, such as in "anti-crime" fluoroscopy and in customs examinations, is generally deprecated. If, in exceptional circumstances that are permitted by the competent authority, such examinations are decided to be essential, they shall be carried out under the supervision of a qualified medical radiologist.

(286) Special care should be taken in the manufacture, testing, installation and repair of sources of ionizing radiations, as in such operations the normal provisions for protection, such as shielding and interlocks, may be rendered inoperative. In circumstances where substantial irradiation by a useful beam could arise, dose rate instruments that give audible signals shall be used.

(287) The deliberate irradiation of persons other than those occupationally or medically exposed is discussed in paragraph 278.

RADIATION AS AN UNWANTED BYPRODUCT

(288) Items of equipment in which electrons are accelerated to an energy in excess of 5 keV should be regarded as potential sources of ionizing radiations, and appropriate protection measures should be taken unless radiation monitoring or experience with similar equipment indicates them to be unnecessary. Such items as electron microscopes, electron beam welders, cathode-ray tubes, high-voltage electronic rectifiers and voltage regulators, vacuum switches, vacuum capacitors, magnetrons, klystrons, transmitting tubes, television and image tubes are all potential sources of x rays; they should be installed, operated, and, where appropriate, constructed, so as to provide adequate protection for all persons. Attention should be paid to persons who test, service and use such equipment, as well as to members of the public if the equipment is installed in accessible places.

(289) The exposure *rate* at any position 5 cm from any outer surface of domestic-type television sets and of television equipment used for projection purposes, closed-circuit applications and the like shall not exceed 0.5 mR/h (see paragraph 40). It is the manufacturer's responsibility to ensure that compliance with this recommendation is achieved. In addition to radiation from the cathode-ray tubes, radiation may arise from high-tension rectifier and shunt voltage-regulator tubes which, because of the radiation transparency of their glass envelopes, may need to be enclosed in protective housings. Persons manufacturing, testing, installing, maintaining or repairing television equipment shall be given special consideration as the protective housings may be removed during such work. Attention is also drawn to the substantial increase in radiation emission that occurs with increasing operating voltage, therefore, television apparatus shall not be adjusted to operate at higher voltages than those for which the protection was designed, and means shall be provided to prevent this from being done.

SURVEY AND MONITORING

GENERAL REQUIREMENTS

(290) The general aspects of survey and monitoring of installations emitting ionizing radiations have been dealt with in ICRP Publication 12 (ref. 12).

(291) Routine operation of any equipment or installation shall be subject to the provisions of paragraph 22.

(292) The surveys referred to in paragraph

22 shall not be confined to radiation measurements but shall include such features as proposed methods of operation, the implementation of restrictions on beam orientation and access to radiation areas. In addition, protective equipment and devices such as gloves and aprons, warning signals and interlocks shall be inspected.

MONITORING

Personal monitoring

(293) Workers who have been identified as being in an operation where doses might exceed three-tenths of the annual MPD should be subject to individual monitoring (see ICRP Publication 9, paragraph 111). For other workers, monitoring of the working environment will usually be sufficient (ICRP Publication 9, paragraph 112) (ref. 9). Recommendations on monitoring are given in ICRP Publication 12 (ref. 12).

(294) No single instrument exists which will accurately measure all possible types of external radiation. It is therefore essential that a competent person shall decide which radiations can conceivably be produced in a given installation, and that he shall specify measuring instruments accordingly. His decisions shall take account of abnormal or faulty conditions as well as of normal operating conditions. It should be remembered that the type as well as the spectrum of the radiation may be changed by shielding materials (e.g. the production of x rays by charged particles).

(295) All radiation measuring devices shall be calibrated, and some simple method of checking constancy should be employed. The calibration should be either specific to the conditions encountered in practice, or should be in the form of response curves from which the calibration factor appropriate to a specific condition may be derived.

Individual monitoring

(296) Personal dosemeters should be designed for optimum reliability, sensitivity and accuracy for the measurement of the types of radiation that occur. Guidance is given in an ICRU Report on Radiation Protection Instrumentation and its Application (ref. 18).

(297) When it is desirable to increase the accuracy of the assessment of the dose to the total body or to the critical organ, consideration must be given to the depth-dose distribution and to the location of the dosemeter and the radiation sources relative to the body. Such consideration may be necessary in the case of excessive exposure but is otherwise rarely required. When there is a potential risk of over-exposure, it may be advisable to wear more than one personal dosemeter, such as a second one at the rear of the trunk, or at other parts of the body which may be of interest. Also the possible contribution of internal radiation exposures to the total body dose shall be considered (see ICRP Publication 9 (ref. 9), paragraphs 53 and 68). Accidental neutron doses may be assessable by the determination of induced activity in the body.

Monitoring of the work place

(298) Photographic films or fluorescent screens may be used to localize small defects in the shielding of radiation sources, which would be difficult to find with a detector having a large sensitive volume.

(299) At locations where there exists a possibility of persons being normally or accidentally exposed to high radiation doses (for example, around reactors) it is advisable to employ strategically located dosimetric systems in order to supplement the personal dosemeters. These systems should be capable of providing additional information about the radiation fields (for instance on the neutron spectrum).

(300) Care should be taken that high frequency electric and strong magnetic fields do not affect the dosimetric properties of the monitoring instruments.

(301) Particular attention should be paid to intermediate energy neutrons scattered from the air or the walls around neutron sources. Some neutron monitors seriously underestimate this component of the neutron spectrum.

(302) Monitoring of equipment operating

above a few MeV shall include measurements of radiation from induced activity in target materials and machine components (see paragraph 49). Much of the activity decays with a short half-life, but a considerable residual activity may persist for weeks or months. This may give rise to an external radiation hazard when changes or repairs have to be made at the machine or during normal maintenance.

(303) If the neutron emission rate of a radiation source exceeds approximately $10^{12} s^{-1}$, it may be necessary to monitor the induced activity in air and/or water.

(304) If it is possible that activity has been induced in objects in or around neutron sources and accelerators, such objects shall not be removed from the controlled areas before appropriate monitoring has been carried out and protective measures instituted.

Environmental monitoring

(305) When necessary, measurements shall be made outside the installation to verify that the conditions are such that the appropriate dose limits for members of the public are unlikely to be exceeded (see ICRP Publications 7 (ref. 7) and 9 (ref. 9)).

RECORD KEEPING

(306) Records of the results of monitoring shall be kept in accordance with the recommendations of ICRP Publication 12 (ref. 12).

(307) Reports of surveys (see paragraph 22) shall be retained for future reference and in any case for such time as may be specified by national and local regulations. Reports shall include recommendations required for the modification of the protection and for limitations in operating procedures. Copies of the plans of the installation should be retained and be readily available at the site (see paragraph 21).

REFERENCES

1. *Recommendations of the International Commission on Radiological Protection* (adopted 9 September 1958), ICRP Publication 1, Pergamon Press, 1959. *Superseded by reference 9.*
2. *Recommendations of the International Commission on Radiological Protection:* Report of Committee II on Permissible Dose for Internal Radiation (1959), ICRP Publication 2, Pergamon Press, 1960.
3. *Recommendations of the International Commission on Radiological Protection:* Report of Committee III on Protection against X Rays up to Energies of 3 MeV and Beta and Gamma Rays from Sealed Sources, ICRP Publication 3, Pergamon Press, 1960.
4. *Recommendations of the International Commission on Radiological Protection:* Report of Committee IV (1953–9) on Protection against Electromagnetic Radiation above 3 MeV and Electrons, Neutrons and Protons (adopted 1962, with revisions adopted 1963), ICRP Publication 4, Pergamon Press, 1964.
5. *Recommendations of the International Commission on Radiological Protection:* Report of Committee V on the Handling and Disposal of Radioactive Materials in Hospitals and Medical Research Establishments, ICRP Publication 5, Pergamon Press, 1965.
6. *Recommendations of the International Commission on Radiological Protection* (as amended 1959 and revised 1962), ICRP Publication 6, Pergamon Press, 1964. *Superseded by reference 9.*
7. *Principles of Environmental Monitoring Related to the Handling of Radioactive Materials:* A Report prepared by a Task Group of Committee 4, ICRP Publication 7, Pergamon Press, 1966.
8. *The Evaluation of Risks from Radiation:* A Report prepared by a Task Group of Committee 1, ICRP Publication 8, Pergamon Press, 1966.
9. *Recommendations of the International Commission on Radiological Protection* (adopted 17 September 1965), ICRP Publication 9, Pergamon Press, 1966.
10. *Recommendations of the International Commission on Radiological Protection:* Report of Committee 4 on Evaluation of Radiation Doses to Body Tissues from Internal Contamination due to Occupational Exposure, ICRP Publication 10, Pergamon Press, 1968.
11. *A Review of the Radiosensitivity of the Tissues in Bone:* A Report prepared for Committees 1 and 2 of the International Commission on Radiological Protection, ICRP Publication 11, Pergamon Press, 1968.
12. *General Principles of Monitoring for Radiation Protection of Workers:* A Report by Committee 4 of the International Commission on Radiological Protection (adopted 24 May 1968), ICRP Publication 12, Pergamon Press, 1969.
13. *Radiation Protection in Schools for Pupils up to the Age of 18 years:* A Report by Committee 3 of the International Commission on Radiological Protection (adopted May 1968), ICRP Publication 13, Pergamon Press, 1970.
14. Report of the RBE Committee to the International Commissions on Radiological Protection and on Radiological Units and Measurements, *Health Physics,* vol. 9, no. 4, pp. 357–84 (1963).
15. *Protection of the Patient in X-ray Diagnosis:* A Report prepared for Committee 3 of the International Commission on Radiological Protection, ICRP Publication 16, Pergamon Press, 1970.
16. International Commission on Radiation Units and Measurements: *Radiation Quantities and Units,* ICRU Report 11 (issued 1 September 1968), ICRU, Washington, 1968.
17. International Commission on Radiation Units and Measurements: *Physical Aspects of Irradiation,* ICRU Report 10b, *National Bureau of Standards Handbook* 85, Washington, 1964.
18. International Commission on Radiation Units and Measurements: *Radiation Protection Instrumentation and its Application* (in preparation).
19. World Health Organization: Declaration of Helsinki—Recommendations Guiding Doctors in Clinical Research, *WHO Chronicle,* vol. 19, pp. 31–32 (1965).
20. World Health Organization/Food and Agriculture Organization of the United Nations: *The Technical Basis for Legislation on Irradiated Food,* WHO Technical Report Series No. 316; FAO Atomic Energy Series No. 6 (1966).

APPENDIX

SUMMARY OF DOSE LIMITS FOR INDIVIDUALS†

Organ or tissue	Maximum permissible doses for adults exposed in the course of their work	Dose limits for members of the public
Gonads, red bone-marrow	5 rems in a year (1) (2) (3)	0.5 rem in a year
Skin, bone, thyroid	30 rems in a year(1) (2)	3 rems in a year (4)
Hands and forearms; feet and ankles	75 rems in a year (1) (2)	7.5 rems in a year
Other single organs	15 rems in a year (1) (2)	1.5 rems in a year

(1) In any one year the MPDs should not be exceeded, but in a period of a quarter of a year up to one-half of the annual MPD, or, for internal exposure, a dose commitment resulting from an intake of a radionuclide equivalent in amount to the intake for one half-year at the maximum permissible concentration, may be accumulated in conformity with the considerations on additivity and multiple organ irradiation given in paragraphs 53 and 68 of ICRP Publication 9. The recommended values for the quarterly quotas may be rounded upward to the next whole number. If necessary, the quarterly quota may be received as a single dose, but the Commission believes that it would be undesirable for doses of this magnitude to be repeated at close intervals.

(2) It may sometimes be necessary to provide flexibility for the MPD for exposure involving the whole body, where the gonads and the red bone-marrow are the critical organs. In such cases (and the Commission believes that they will be infrequent) it will be justifiable to permit the quarterly quota to be repeated in each quarter of the year, provided that the total dose accumulated at any age over 18 years does not exceed $5(N-18)$ rems, where N is the age in years. Under special conditions discussed in paragraphs 66 and 67 of ICRP Publication 9, single doses or a series of doses up to a total of twice the annual limit may be permitted to critical organs, subject to certain restrictions.

(3) The recommendation permitting dose accumulation at rates up to 3 rems in a quarter (as derived from paragraphs 54 and 56 of ICRP Publication 9) should not apply in circumstances involving abdominal exposure of women of reproductive capacity. Such women should be occupationally employed only under conditions where the dose to the abdomen is limited to 1.3 rems in a quarter, corresponding to 5 rems per year delivered at an even rate. Under these conditions, the dose to an embryo during the critical first 2 months of organogenesis would normally be less than 1 rem, a dose which the Commission considers to be acceptable. When a pregnancy has been diagnosed, arrangements should be made to ensure that the exposure of the woman be such that the dose to her foetus, accumulated during the remaining period of the pregnancy, does not exceed 1 rem. Practical experience indicates that the dose to the foetus during this period is usually substantially less than 1 rem. In practice, many of the women in this category work with diagnostic x-ray equipment. For exposures resulting from x-ray equipment operated at low kilovoltage, the recommendation will usually be satisfied even if the pregnant woman continues to be occupationally employed under circumstances where the dose to the abdomen is limited to 1.3 rems in a quarter. In the case of exposures received from x-ray equipment operated at high kilovoltage, it will usually be necessary to assess the dose received by the foetus.

(4) 1.5 rems in a year to the thyroid of children up to 16 years of age.

† For a full discussion of dose limits the reader is referred to ICRP Publication 9 (ref. 9, main text).

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